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USAAEFA PROJECT NO. 82-13

AIRWORTHINESS AND FLIGHT CHARACTERISTICS (A&FC) TEST OF THE EH - 1X / EH - IH HELICOPTER CONFIGURATIONS

AD-A144 881

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FINAL REPORT

USAAEFA

UNITED STATES ARMY AVIATION ENGINEERING FLIGHT ACTIVITY
EDWARDS AIR FORCE BASE, CALIFORNIA 93523

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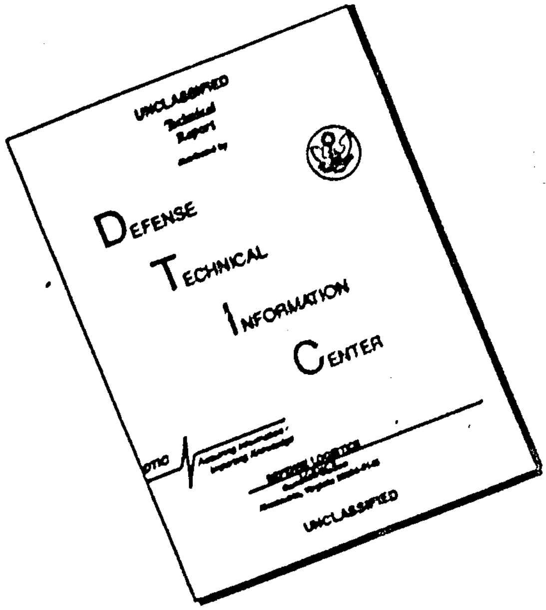

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ALQ-144 Countermeasures Jammer	Hot Metal Plus Plume Infrared Suppressor
Change in Drag Characteristics	Level Flight Performance
EH-1X/EH-1H Helicopter	M-130 Chaff/Flare Dispensers
Equivalent Flat Plate Area	Standard UH-1H Helicopter

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The US Army Aviation Engineering Flight Activity conducted level flight performance tests of five EH-1X/EH-1H helicopter configurations to determine the change in drag characteristics with the addition of external mission equipment to the standard UH-1H helicopter configuration. Comparison of data from a baseline test configuration with previously published UH-1H and YUH-1H data indicated approximately 8.0 ft^2 increase in equivalent flat plate area which was attributed to the external mission antennas, low reflective infrared/optical

paint, and heat suppression kit with vertical exhaust ejector. Installation of the M-130 chaff/ flare dispensers resulted in a further increase in equivalent flat plate area of 5.0 ft^2. Replacing the vertical exhaust ejector with the hot metal plus plume infrared suppressor, including the ALQ-144 countermeasures jammer resulted in a reduction in equivalent flat plate area of 1.5 ft^2. Installation of the direction finding antennas resulted in no measurable increase in drag. Addition of all external mission equipment and the hot metal plus plume exhaust resulted in a total increased equivalent flat plate area of approximately 11.5 ft^2 from the standard UH-1H helicopter.

DEPARTMENT OF THE ARMY

HEADQUARTERS, US ARMY AVIATION SYSTEMS COMMAND

4300 GOODFELLOW BOULEVARD, ST. LOUIS, MO 63120

REPLY TO
ATTENTION OF

DRSAV-E

SUBJECT: Directorate for Engineering Position of the Final Report of USAAEFA Project No. 82-13, Airworthiness and Flight Characteristics (A&FC) Test of the EH-1X/EH-1H Helicopter Configurations

SEE DISTRIBUTION

1. The purpose of this letter is to establish the Directorate for Engineering position on the subject report. The report provides excellent documentation of the delta drag characteristics and direction finding (DF) antenna temperature survey of both the EH-1X and EH-1H helicopter configuration as compared to the UH-1H helicopter. Also noteworthy is the excellent extensive photographic and written documentation of the external configurations of the EH-1X and EH-1H helicopters for future reference.

2. This Directorate agrees with the Conclusions and Recommendation stated in the report. The A&FC performance data will be used to update the EH-1X and EH-1H Operator's Manuals.

FOR THE COMMANDER:

RONALD E. GORMONT
Acting Director of Engineering

TABLE OF CONTENTS

INTRODUCTION

BACKGROUND

1. The EH-1X and EH-1H helicopters are special Quick Fix electronic mission aircraft developed under management of the Special Electronic Mission Aircraft Product Manager. Both aircraft are equipped with the AN/TLQ-17A electronics countermeasures (ECM) jammer while the EH-1X is further equipped with direction finding (DF) equipment developed by the Electronic Systems Laboratory (ESL), a division of TRW Defense Systems Group, TRW Inc., Sunnyvale, California. The US Army Aviation Engineering Flight Activity (USAAEFA) conducted a qualitative flight evaluation of the EH-1X (ref 1, app A) on 18 November 1981. The US Army Research and Development Command (AVRADCOM) requested USAAEFA to conduct a limited airworthiness and flight characteristics (A&FC) test (ref 2, app A) prior to final US Army acceptance of the aircraft from ESL and their issuance to using units. A test plan for the A&FC (ref 3, app A) was submitted in January 1983 and approved by AVRADCOM on 4 March 1983.

TEST OBJECTIVE

2. The objective of this limited A&FC was to conduct level flight performance testing to determine the drag characteristics of the EH-1X/EH-1H helicopter configurations for use in updating the operator's manual (ref 4, app A) for performance planning.

DESCRIPTION

3. The test aircraft (S/N 69-15920) was a production UH-1H aircraft modified to the Quick Fix II configuration (EH-1X) by the installation of the external antennas, low reflective infrared (IR)/optical paint, heat suppression kit, the M-130 Aircraft General Purpose Dispensing System (AGPDS), the hot metal plus plume (HMPP) IR suppressor, and the ALQ-144 countermeasures (IRCM) jammer. The aircraft was powered by an AVCO Lycoming T53-L-13B engine which was transmission limited to 1100 shaft horsepower (shp). The main transmission mounted generator was replaced by a 30 kilovolt-ampere alternator to provide the electrical power required by the installed mission equipment. Internal mission equipment and equipment racks were not installed. A detailed description of the test aircraft is presented in appendix B and the operator's manual as amended by a draft change (ref 5, app A).

TEST SCOPE

4. The A&FC was conducted at Edwards AFB, California (2302 ft MSL) during the period 26 July to 19 September 1983. A total of 21 test flights were flown resulting in 19.5 productive flight hours. Five different configurations were evaluated as described in the Results and Discussion section. These various configurations were obtained by adding or removing the DF antennas, AGPDS, and HMPP IR suppressor/IRCM jammer. Flight restrictions contained in the airworthiness release (ref 6, app A) and the operator's manual were observed during this evaluation. Level flight performance tests were conducted using the constant weight to pressure ratio (W/δ) and a constant main rotor speed to temperature ratio ($N_R/\sqrt{\theta}$) of 324 rpm. The thrust coefficient (C_T) range was from 31 to 40 x 10^{-4}. All flights were flown at zero sideslip. Test conditions are shown in table 1. A limited temperature survey of the DF antennas was also conducted after installation of the HMPP IR suppressor.

TEST METHODOLOGY

5. Established level flight test techniques and data reduction procedures (ref 7, app A) were used. The temperature survey on the DF antennas was conducted utilizing temperature sensitive tapes. Test instrumentation consisted of calibrated cockpit gauges and data were hand recorded. A detailed listing of test instrumentation is contained in appendix C. Test techniques and data analysis methods are described in appendix D.

Table 1. Level Flight Test Conditions[1]

Configuration[2] (Configuration No.)	Average Longitudinal Center of Gravity (FS)	Average Gross Weight (lb)	Average Density Altitude (ft)	Average OAT (°C)	Average[3] Rotor Speed (rpm)	Average Thrust Coefficient
EH-1X(1)	135.2	7480	6610	24.0	329	0.003100
	135.3	8390	6640	21.0	327	0.003523
	135.9	8320	10,540	15.0	324	0.004018
EH-1X(2)	136.4	7550	5850	20.0	326	0.003114
	136.3	8380	6130	17.5	326	0.003486
	136.3	8340	10,100	12.5	323	0.003996
EH-1X(3)	135.2	7690	5710	24.0	329	0.003101
	135.3	8040	8050	23.0	328	0.003505
	135.9	8300	10,440	15.0	324	0.003995
EH-1H(4)	135.8	7380	6930	23.0	329	0.003089
	135.9	7950	8520	23.5	329	0.003495
	135.9	8300	10,720	16.5	326	0.003981
EH-1H(5)	135.7	7590	6090	22.5	329	0.003096
	135.8	8140	7330	19.5	327	0.003492
	136.4	8230	10,250	11.0	322	0.003987

NOTES:

[1]All configurations were flown at mid lateral cg, zero sideslip, and with the ECM jammer antenna extended
[2]Configurations presented in table 2.
[3]Average referred main rotor speed ($N_R/\sqrt{\theta}$) was 324 rpm.

RESULTS AND DISCUSSION

GENERAL

6. Level flight performance tests were conducted to determine the drag characteristics of the EH-1X/EH-1H helicopter configurations for inclusion in the operator's manual. Comparison of data from the EH-1X(1) baseline configuration with previously published UH-1H and YUH-1H data indicated approximately 8.0 ft^2 increase in equivalent flat plate area (F_e) which was attributed to external mission antennas, low reflective IR/optical paint, and heat suppression kit with vertical exhaust ejector. Other significant results were a 5.0 ft^2 drag increase for the M-130 AGPDS installation and 1.5 ft^2 drag decrease for the HMPP IR suppressor installation. No measurable drag increase was observed with addition of the DF antennas. Installation of all external mission equipment and HMPP IR Suppressor resulted in a total F_e increase of approximately 11.5 ft^2 from the standard UH-1H configuration. A limited temperature survey with HMPP IR suppressor installed indicated that temperatures were within limits at the conditions tested, both internally and externally, on all four DF antennas.

LEVEL FLIGHT PERFORMANCE

General

7. Level flight performance tests were conducted to determine the power required for level flight in the five configurations shown in table 2. The thrust coefficient (C_T) range was from 31 to 40 x 10^{-4}. The constant referred rotor speed constant gross weight to pressure ratio technique was used to maintain a constant C_T. The EH-1X(1) was used as a baseline configuration for comparison since the test aircraft could not be configured to the UH-1H configuration. EH-1X(1) level flight performance data was compared with previously published UH-1H and YUH-1H data to determine the change in F_e with the addition of external mission equipment to the UH-1H configuration. All other configurations were compared to the EH-1X(1) baseline data. A summary of change in F_e for the various configurations is presented in table 2.

Configuration Variation

8. The EH-1X(1) configuration was used as the baseline configuration for all F_e comparisons for this report. Level flight performance data for this configuration are presented in figures 1 through 5, appendix E. EH-1X(1) level flight performance data was compared with previously published UH-1H data obtained on aircraft S/N 69-15532 (ref 8, app A). This comparison (fig. 6,

Table 2. Test Configurations and Results

Configuration[1] (Configuration No.)	HMPP Suppressor/ IRCM Jammer	M-130 AGPDS	DF Antennas	ECM Jammer Antenna	ΔF_e[2] from Baseline EH-1X(1)	ΔF_e[2, 3] from Standard UH-1H
EH-1X(1) Baseline	OFF[4]	OFF	ON	ON	0	8.0
EH-1X(2)	OFF[4]	ON	ON	ON	5.0	13.0
EH-1X(3)	ON	ON	ON	ON	3.5	11.5
EH-1H(4)	ON	ON	OFF	ON	3.5	11.5
EH-1H(5)	ON	OFF	OFF	ON	-1.5	6.5

NOTES:

[1]All EH-1X/EH-1H configurations included external mission antennas described in appendix B, low reflective IR/optical paint, and heat suppression kit.
[2]ΔF_e = change in equivalent flat area
[3]EH-1X(1) level flight performance data was compared to UH-1H data presented in ref 8, app A at C_T = 0.00367 to determine the ΔF_e resulting from the addition of external mission equipment. All other configurations were then compared with the EH-1X(1) baseline data.
[4]Flown with vertical exhaust ejector

app E) indicates that addition of external mission antennas, low reflective IR/optical paint, and the heat suppression kit with vertical exhaust ejector resulted in a F_e increase of approximately 8.0 ft^2 from the UH-1H configuration. An additional comparison of the EH-1X(1) data with previously published data on a YUH-1H (ref 9, app A) verified this increase in F_e.

9. Level flight performance data for the EH-1X(2) configuration are presented in figures 7 through 9, appendix E. Comparison with the EH-1X(1) configuration indicates an F_e increase of 5.0 ft^2 attributed to the M-130 AGPDS installation. The EH-1X(2) which features the addition of all Quick Fix II external mission equipment with vertical exhaust ejector shows a total F_e increase of approximately 13.0 ft^2 from the UH-1H.

10. Level flight performance data for the EH-1X(3) and EH-1H(4) configurations are presented in figures 10 through 15, appendix E. Comparison of both these configurations with the EH-1X(1) indicates an F_e increase of 3.5 ft^2 with a 5.0 ft^2 increase attributed to the M-130 AGPDS and a 1.5 ft^2 decrease attributed to the HMPP IR suppressor/IRCM jammer installation. This comparison indicated that the DF antennas contributed no measurable drag increase since the only difference between the EH-1X(3) and the EH-1H(4) was the DF antenna installation. The EH-1X(3) configuration represents the Quick Fix II mission configuration (EH-1X) in that all external mission equipment is installed and results in a total F_e increase of approximately 11.5 ft^2 from the UH-1H.

11. Level flight performance data for the EH-1H (5) configuration are presented in figures 16 through 18, appendix E. Comparison with the EH-1X(1) configuration indicates an F_e decrease of 1.5 ft^2 which verifies the drag decrease caused by substitution of the HMPP IR suppressor/IRCM jammer for the vertical exhaust ejector of the UH-1H heat suppressor kit. This comparison also verifies that the DF antennas contributed no measureable drag increase. The EH-1H(5) shows a total F_e increase of approximately 6.5 ft^2 from the UH-1H.

TEMPERATURE SURVEY

12. A temperature survey was conducted prior to initial performance testing on the EH-1X(3) after installation of the HMPP IR Suppressor/IRCM Jammer. Temperature sensitive tapes were applied internally and externally to the DF antennas as shown in photo 1. The maximum allowable limits for the temperature survey

were 121°C internally and 149°C externally. The temperatures were sampled during in-ground effect (IGE) and out-of-ground effect (OGE) hover at maximum continuous power. Hover time was limited to 30 minutes for both IGE and OGE tests. Temperature survey results are presented in tables 3 and 4. Observed temperatures, both internally and externally, did not exceed maximum allowable limits.

Table 3. Temperature Survey Results IGE (30 Minutes)

Antenna Number	External (°C)	Internal (°C)	OAT (°C)
1	<93	107	
2	<93	107	35
3	121	107	
4	<93	107	

Table 4. Temperature Survey Results OGE (30 Minutes)

Antenna Number	External	Internal (°C)	OAT (°C)
1		107	
2		107	34
3	Not Recorded	<93	
4		<107	

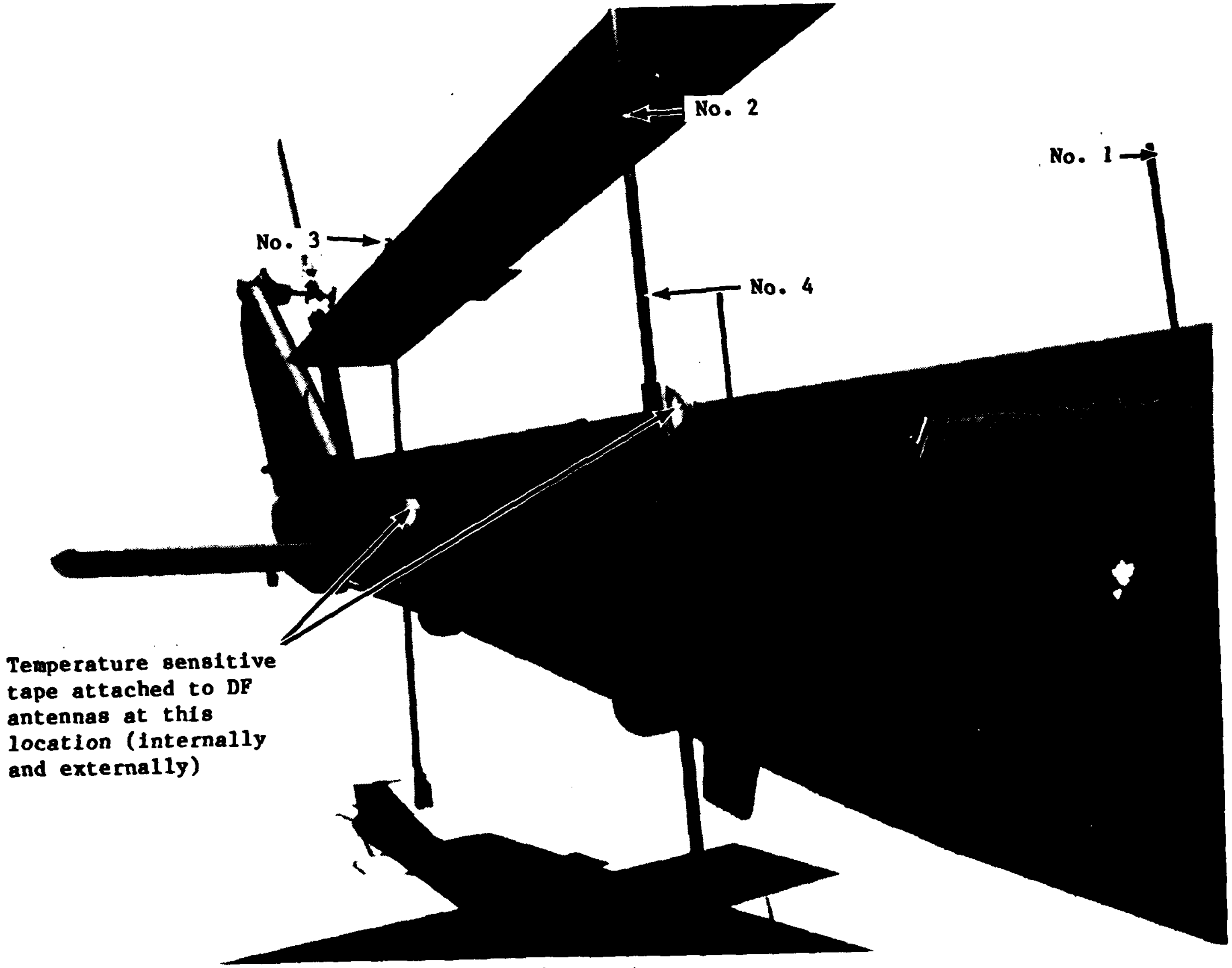


Photo 1. DF Antennas.

CONCLUSIONS

13. Modification of the UH-1H configuration by addition of the external mission antennas, low reflective IR/optical paint, and heat suppression kit with vertical exhaust ejector resulted in an F_e increase of approximately 8.0 ft^2 (para 8).

14. Based on the A&FC flight tests of the EH-1H/EH-1X, installation of the M-130 AGPDS resulted in an F_e increase of 5.0 ft^2 (para 9).

15. Substitution of the HMPP IR suppressor/IRCM jammer for the vertical exhaust ejector of the UH-1H heat suppressor kit resulted in an F_e decrease of 1.5 ft^2 (paras 10 and 11).

16. Installation of DF antennas resulted in no measureable drag increase (paras 10 and 11).

17. Addition of all Quick Fix II external mission equipment with the vertical exhaust ejector resulted in an F_e increase of approximately 13.0 ft^2 from the UH-1H configuration (para 9).

18. Addition of all Quick Fix II external mission equipment with HMPP IR suppressor/IRCM jammer (EH-1X) resulted in an increase F_e of approximately 11.5 ft^2 from the UH-1H configuration (para 10).

19. Observed temperatures on the DF antennas, both internally and externally, did not exceed maximum allowable limits when the HMPP IR suppressor/IRCM jammer was installed (para 12).

RECOMMENDATION

20. Include the flight test data from this A&FC report in the operator's manual for the EH-1H/EH-1X.

APPENDIX A. REFERENCES

1. Final Report, USAAEFA Project No. 81-19, *EH-1X Qualitative Flight Evaluation*, 21 December 1981.

2. Letter, AVRADCOM DRDAV-DI, 25 January 1983, subject: Airworthiness and Flight Characteristics (A&FC) Test of the EH-1X/EH-1H Helicopter Configurations.

3. Test Plan, USAAEFA Project NO. 82-13, *Airworthiness and Flight Characteristics (A&FC) Test of the EH-1X/EH-1H Helicopter Configuration*, January 1983.

4. Technical Manual, TM 55-1520-210-10, *Operator's Manual, Army Model UH-1D 1H and EH-1H Helicopters*, 18 May 1979.

5. Draft Change Source Data for TM 55-1520-210-10, *Operator's Manual, Army Model EH-1X Helicopter*, 5 November 1981.

6. Letter, AVRADCOM DRDAV-DI, 10 August 1983, subject: Airworthiness Release, EH-1X S/N 69-75920, Quick Fix II Helicopter to Conduct Limited Airworthiness and Flight Characteristics (A&FC) Level Flight Drag Characteristics of the EH-1X/EH-1H Configurations, with revision 1 dated 11 August 1983.

7. Pamphlet, USAMC, AMCP 706-204, *Engineering Design Handbook, Helicopter Performance Testing*, August 1974.

8. Final Report, USAAEFA Project No. 81-01-3, *Fuel Conservation of US Army Helicopters, Part 3, UH-1H Flight Testing*, August 1982.

9. Final Report, USAAVSCOM Project No. 66-04, *Engineering Test Flight, YUH-1H Helicopter, Phase D (Limited)*, November 1970.

APPENDIX B. DESCRIPTION

GENERAL

1. The EH-1X test aircraft (photo 1) was a production UH-1H helicopter modified to a Quick Fix II configuration. Significant features included Quick Fix external mission antennas, low reflective infrared (IR)/optical paint, and heat suppression kit with the vertical exhaust ejector replaced by a hot metal plus plume (HMPP) IR suppressor with the AN/ALQ-144 (IRCM) jammer (photos 2 and 3). The EH-1X electrical system utilized the engine driven starter-generator as the main DC power source. A 30 kilovolt-ampere alternator driven by the main transmission supplied the AC power for the mission equipment. A converter (transformer-rectifier) unit provided mission DC power and emergency DC power for aircraft systems in the event of a main generator failure. Principle dimensions and features of the EH-1X are presented in the operator's manual (ref 4, app A) as amended by draft change source data (ref 5, app A).

EH-1X/EH-1H EXTERNAL CONFIGURATIONS

2. Five different configurations were obtained by adding or removing the M-130 AGPDS, HMPP IR suppressor/IRCM jammer, and DF antennas. All configurations included the low reflective/IR optical paint, heat suppression kit (with either vertical ejector or HMPP), and ECM antenna (photos 4 and 5). The various configurations are shown in table 1 and described below.

a. The baseline EH-1X(1) configuration featured the standard heat suppression kit with vertical exhaust ejector (photos 6 and 7) and DF antennas. The EH-1X(2) configuration (photos 8 through 12) was similar to the EH-1X(1) configuration with the M-130 AGPDS (photos 13 and 14) installed.

b. The EH-1X(3) configuration (photos 15 and 16) had the M-130 AGPDS, DF antennas, and vertical ejector replaced with the HMPP IR suppressor/IRCM jammer.

c. The EH-1H(4) was similar to the EH-1X(3) configuration except the DF antennas (photo 17) were removed. The antenna attaching points were covered with metal plates.

d. The EH-1H(5) configuration was the same as the EH-1H (4) configuration except the M-130 AGPDS were removed. The aircraft hard points for mounting the M-130 AGPDS are shown in photo 18.

Miscellaneous mission antennas installed on all configurations tested are shown in photos 19 through 21. A complete list of external equipment mounted on the EH-1X(3) is shown in table 2.

Table 1. Aircraft Configuration[1]

Configuration (Configuration No.)	HMPP Suppressor/ IRCM Jammer[2]	M-130 AGPDS[3]	DF[4] Antennas	ECM Jammer Antenna[5]
EH-1X(1)	OFF[6]	OFF	ON	ON
EH-1X(2)	OFF[6]	ON	ON	ON
EH-1X(3)	ON	ON	ON	ON
EH-1H(4)	ON	ON	OFF	ON
EH-1H(5)	ON	OFF	OFF	ON

NOTES:

[1]All configurations included low reflective infrared/optical paint, heat suppression kit, and ECM antenna
[2]AN/ALQ-144 IRCM Jammer (photos 2 and 3)
[3]Flare/Chaff Dispensers (photos 13 and 14)
[4]Tail boom mounted dipole antennas (photo 12)
[5]AN/TLQ-17A antenna (photos 4 and 5)
[6]Flown with vertical exhaust ejector (photo 6)

Table 2. EH-1X (3) External Equipment

Part	Identifying Photographs	Comments
HMPP Suppressor/IRCM Jammer (AN/ALQ-144)	2 and 3	Exhaust ejector and modified aft engine cowl
Radar warning antennas APR-39	9	Left and right nose mounted
FM Homing Antenna (FM 10-120)	9 and 10	Left and right side mounted
ECM Jammer Antenna (AN/TLQ-17A)	4, 5 and 11	Bottom aft tailboom (retractable)
BITE Antenna	11	Bottom side tailboom
DF Antennas	12 and 17	Left and right side tailboom
Radar Warning Antennas (APR-39)	12	Rear tailboom
Chaff Dispenser (M-130)	12 and 13	Left side
Flare Dispenser (M-130)	12 and 14	Right side
Standard Heat Suppression Kit	6 and 7	Exhaust ejector, engine cowl heat shields and oil cooler heat shield
VOR Antennas[1] AS 1304/ARN	6	Left and right aft tailboom
Radar Altimeter Antennas (APN 209)	19	Front bottom side
IFF Antennas[1] (AT-884/APX)	19	
TACO G1169 Antenna	19	
Radar Warning Antenna (AS 2890/APR 39)	19	
Marker Beacon Antenna[1] (AT 64A/ARN)	19	
TACO G1169 Antenna	20	Aft bottom center
TACAN antenna (AT-741)	20	Aft bottom left
VHF/FM Antenna[1] (AS 4070/ARC)	21	Roof Mounted
UHF/VHF Antenna[1] (AT-1108/ARC)	21	
TACAN Antenna (AT-741)	21	
ADF Sense Antenna[1] 205-075-325-1	21	

NOTE:

[1]Standard UH-1H external equipment

UH-1H EXTERNAL CONFIGURATION

3. The UH-1H aircraft, US Army S/N 69-15532 (photo 22), was a production UH-1H aircraft with gloss lacquer paint and a standard engine exhaust assembly. The cargo hook was removed and the main generator driven off the transmission provided D.C. electrical power. The standby generator driven off the engine provided emergency electrical power in the event of main generator failure. A list of the external mounted equipment on the UH-1H aircraft is presented in table 3. External equipment is also identified in photos 22 and 23. Further descriptive material is presented in reference 4, appendix A.

Table 3. UH-1H S/N 69-15532 External Configuration

Part	Comments
FM Antenna[1] AS 1703/ARC	Upper tailboom pylon
VOR Antennas[2] AS 1304/ARN	Left and right side aft tailboom
Strobe beacon	Bottom side tailboom
Anti Collision light[2]	Upper engine cowl
OAT probe[1]	Forward bottom center
DME Antenna[1]	Forward bottom left
IFF Antenna[2] (AT-884/APX)	Forward bottom center
Marker Beacon Antenna[2] AT-64A/ARN	
UHF/VHF Antenna[2] (AT-1108/ARC)	Roof mounted
ADF Sense Antenna[2] 205-075-325-1	
FM Homing Antenna[1] AS-1922/ARC	

NOTES:

[1]Not installed on EH-1X
[2]Standard UH-1H external equipment

Photo 1. EX-1X Sideview

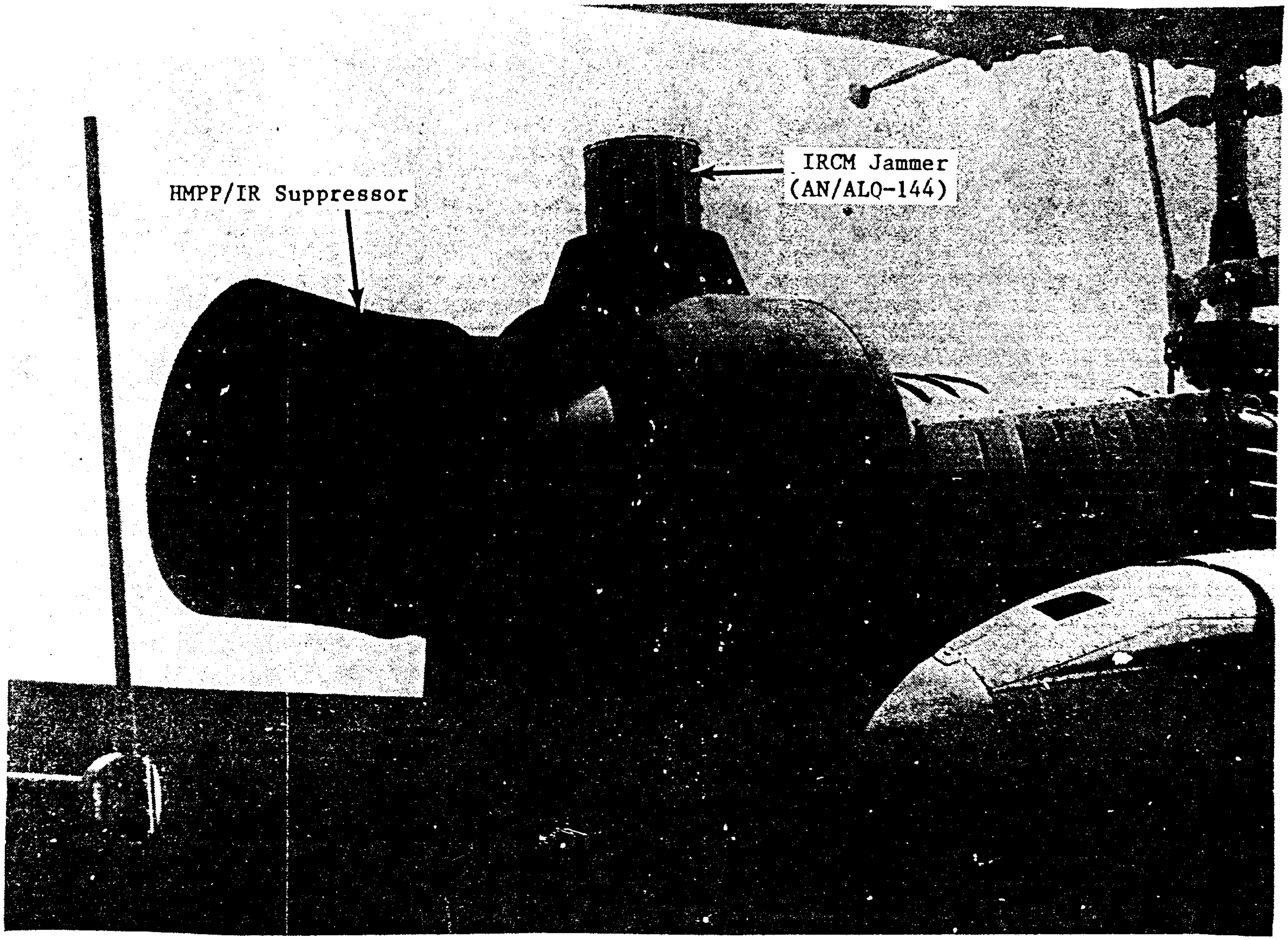


Photo 2. HMPP/IR Suppressor, Right Rear Quartering View

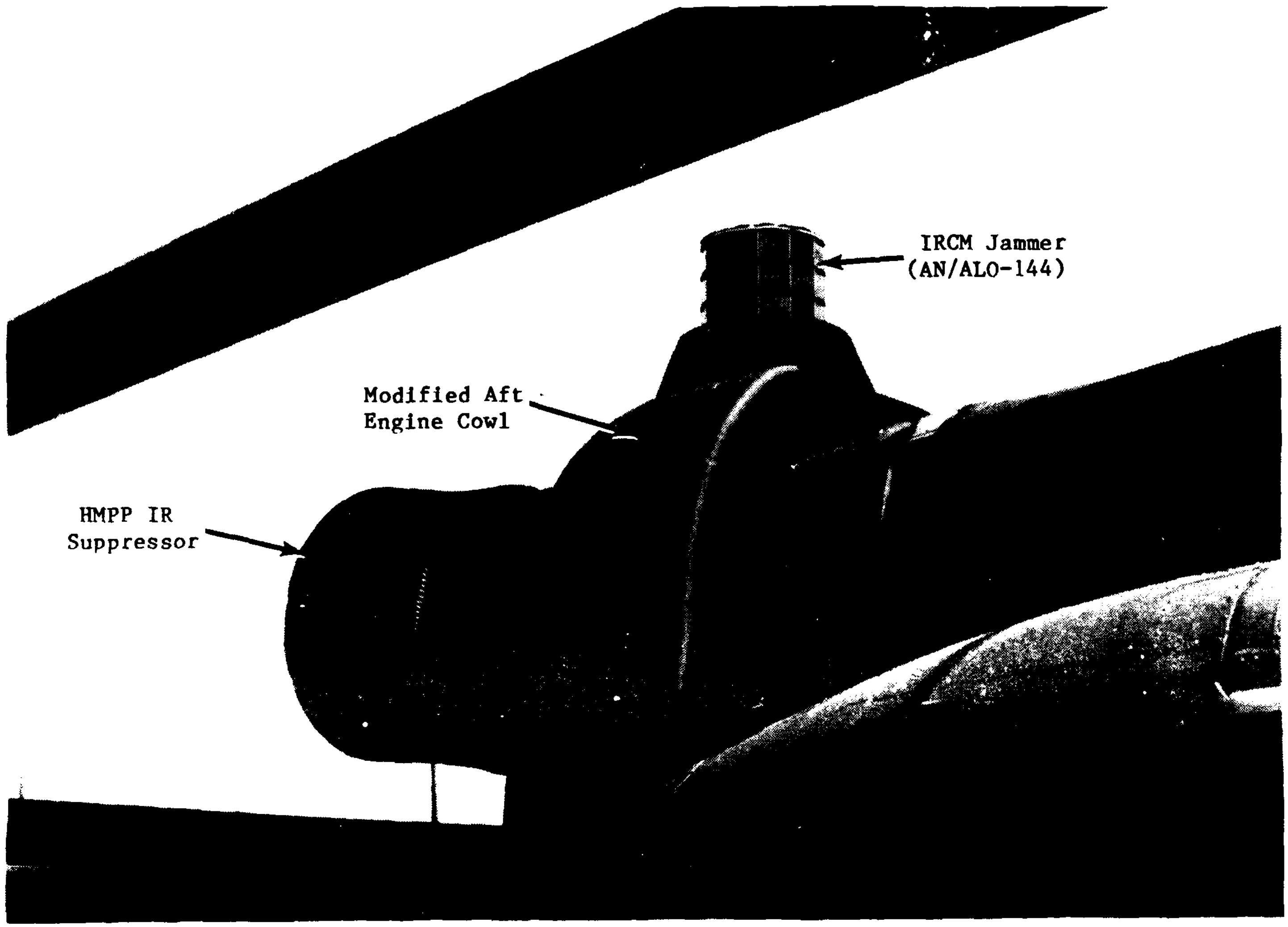


Photo 3. HMPP/IR Suppressor, Right Forward Quartering View

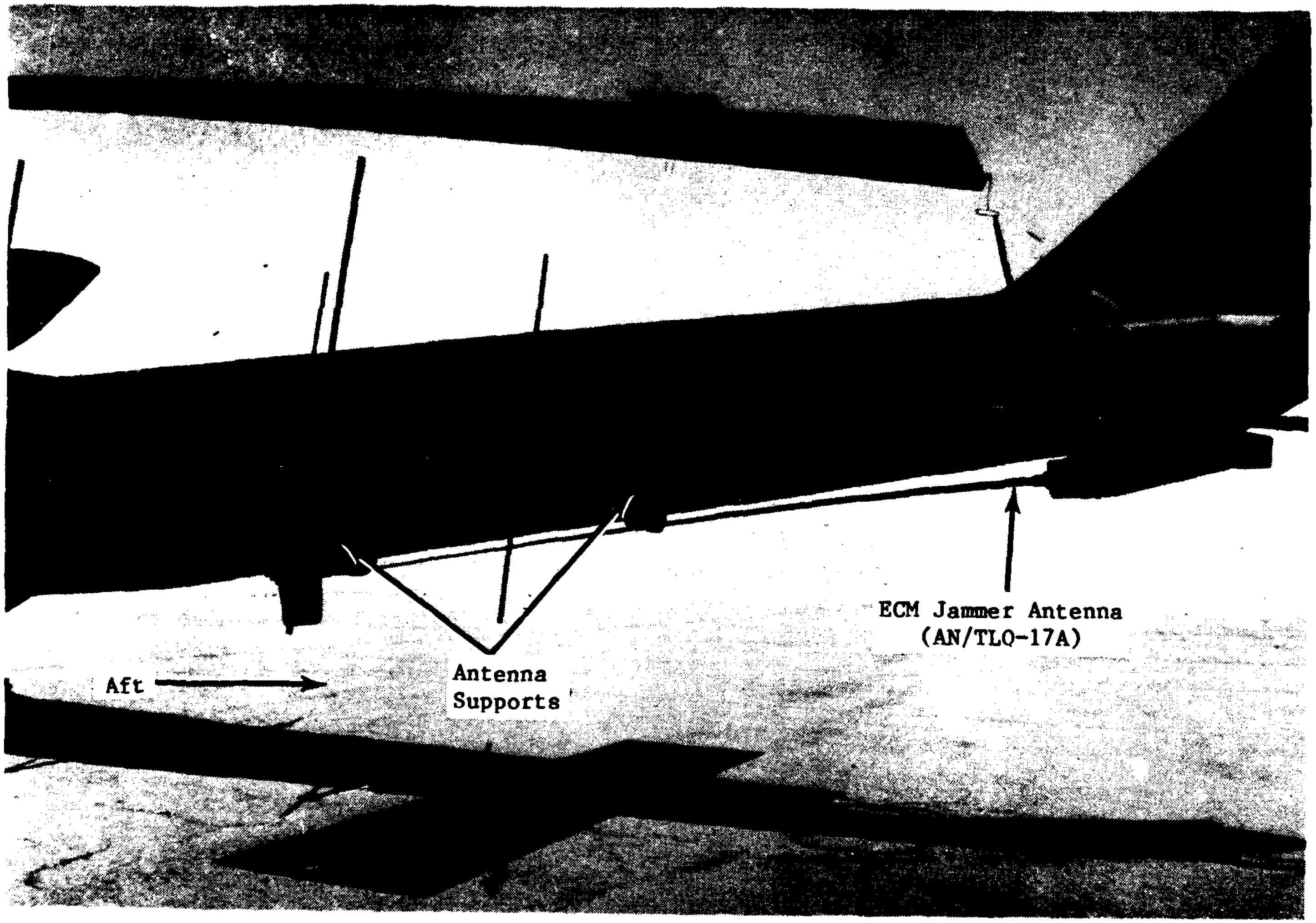


Photo 4. ECM Jammer Antenna (AN/TLQ-71A)

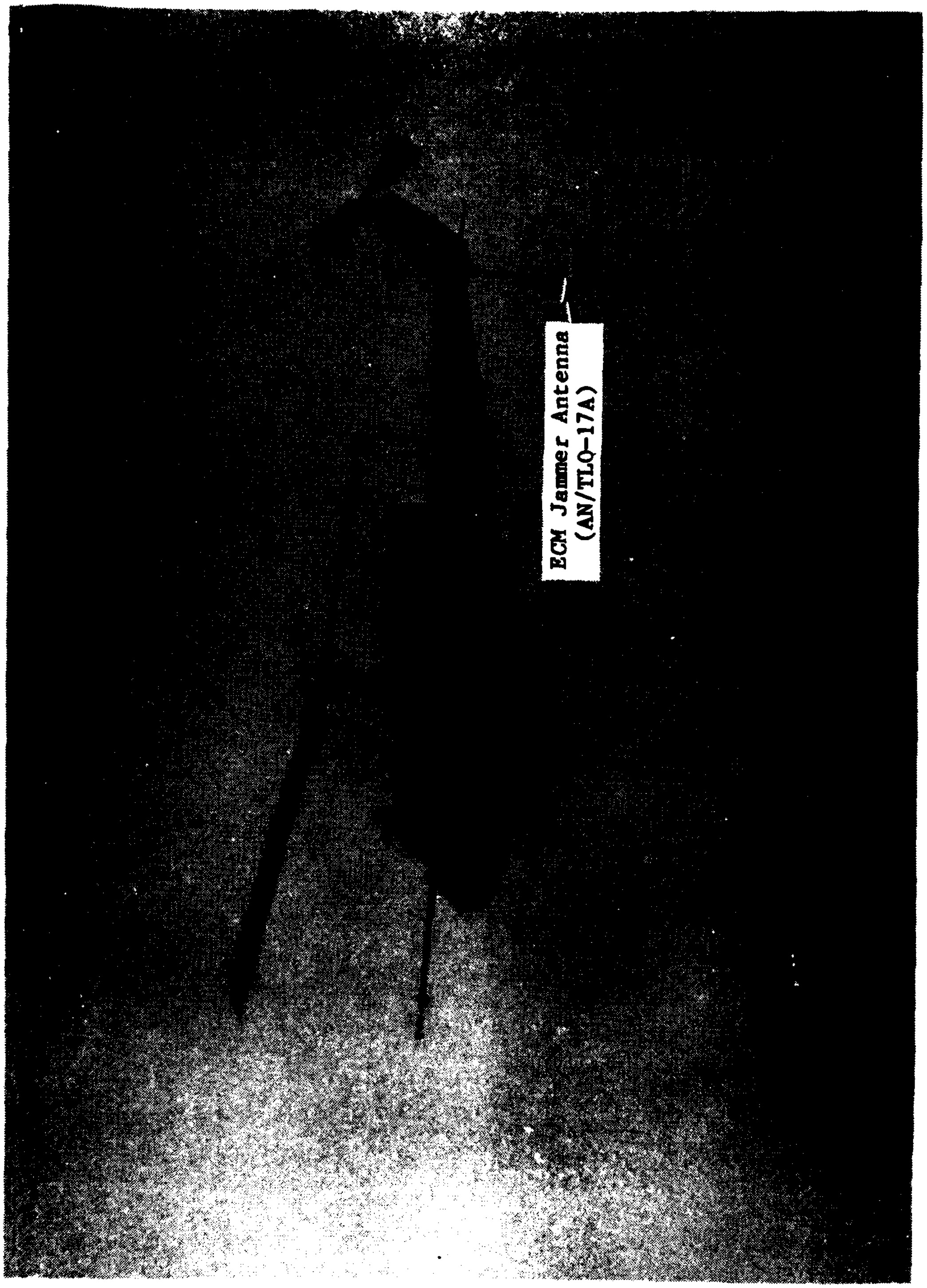


Photo 5. ECM Jammer Antenna (Extended Position)

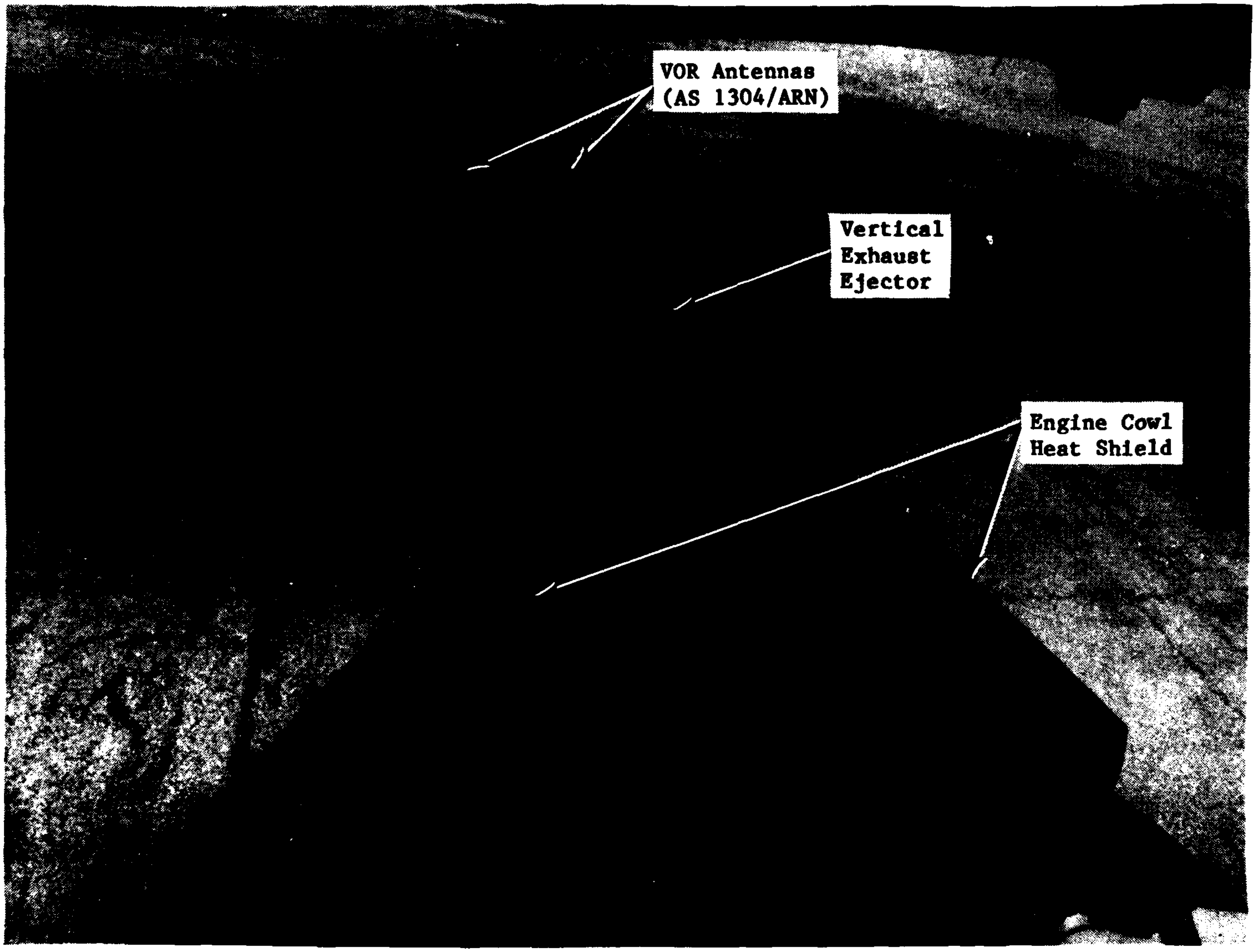


Photo 6. Standard Heat Suppression Kit

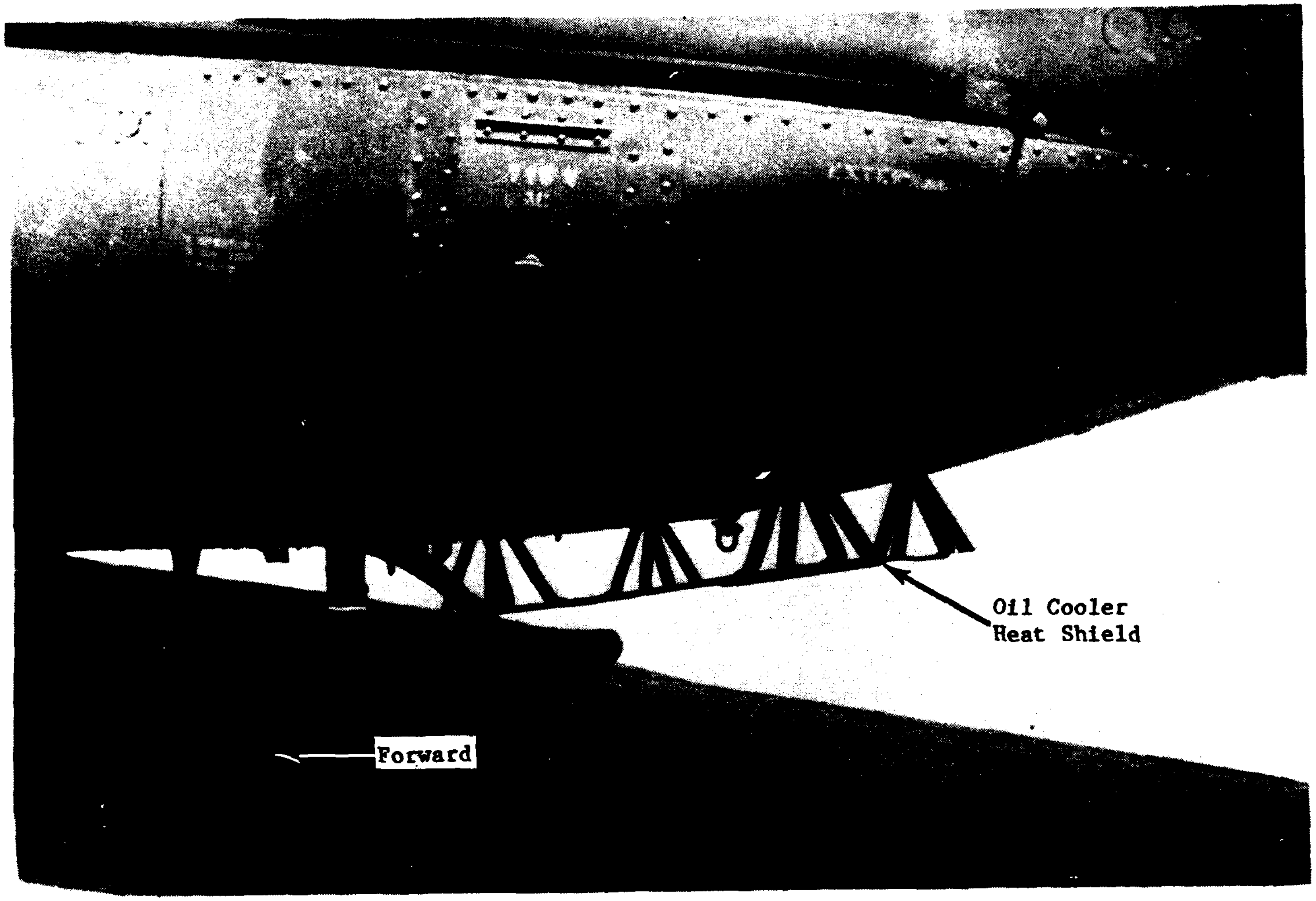


Photo 7. Standard Heat Suppression Kit

Photo 8. EH-1X(2) Right Side View

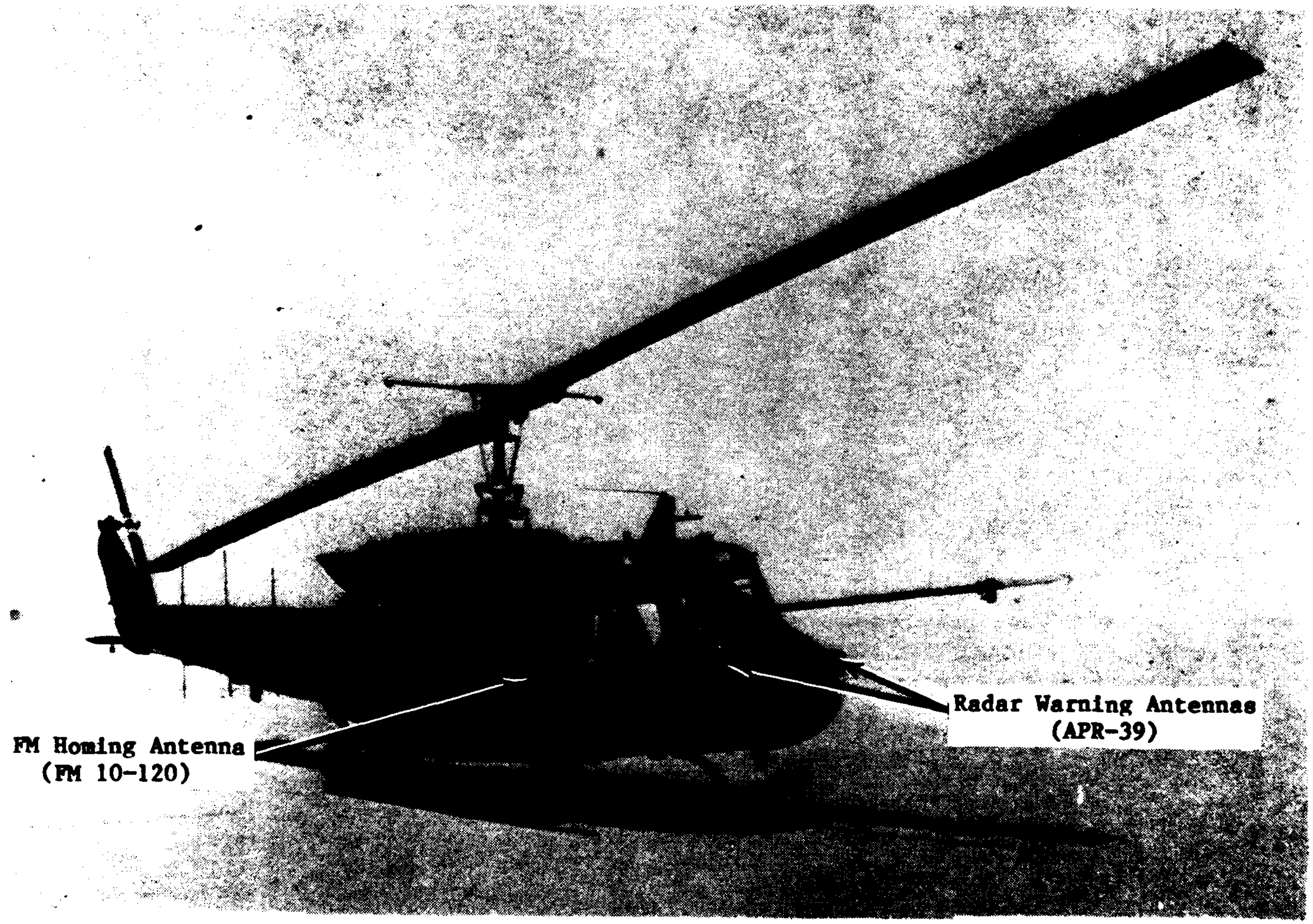


Photo 9. EH-1X(2) Right Front Quartering View

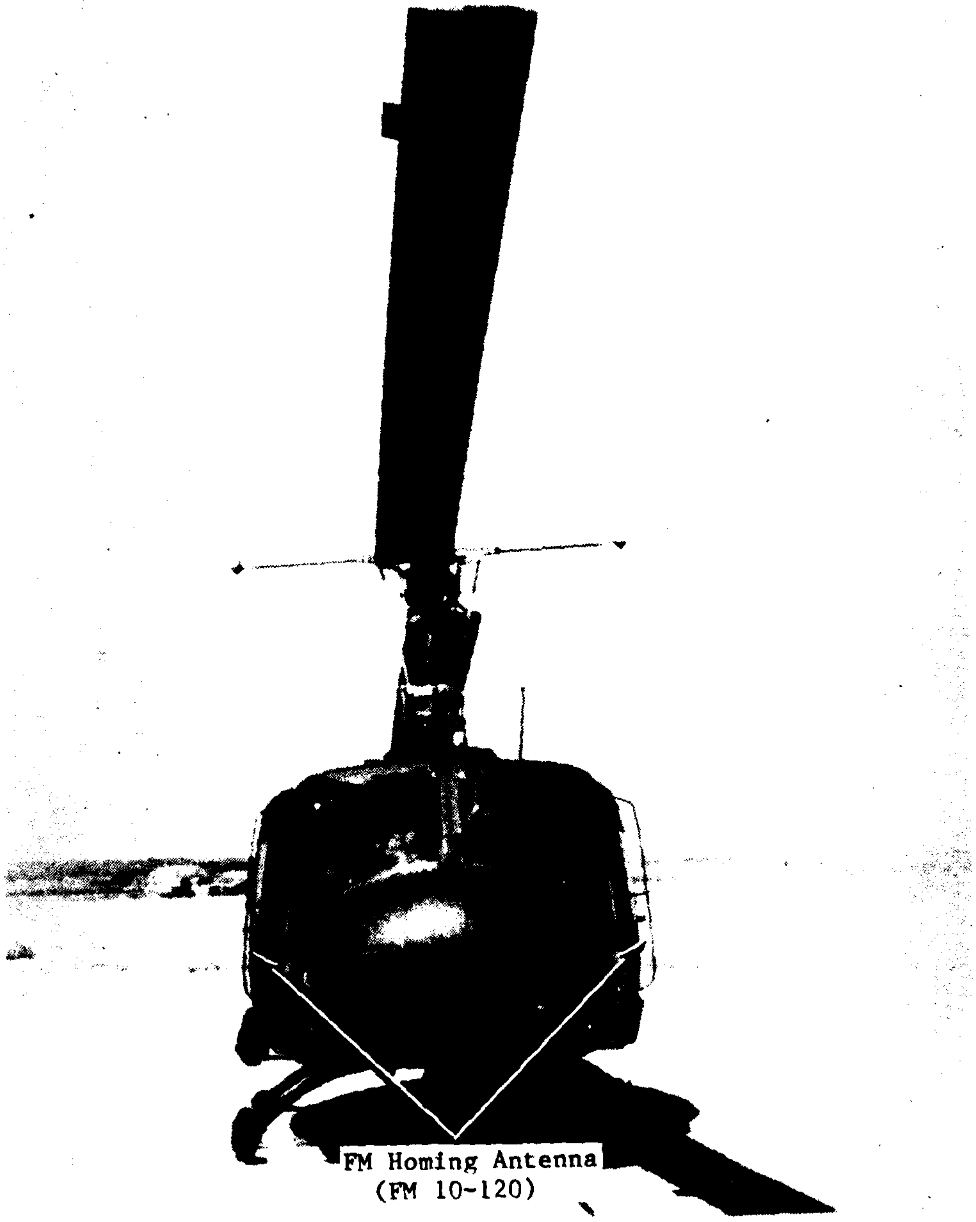


Photo 10. EH-1X(2) Front View

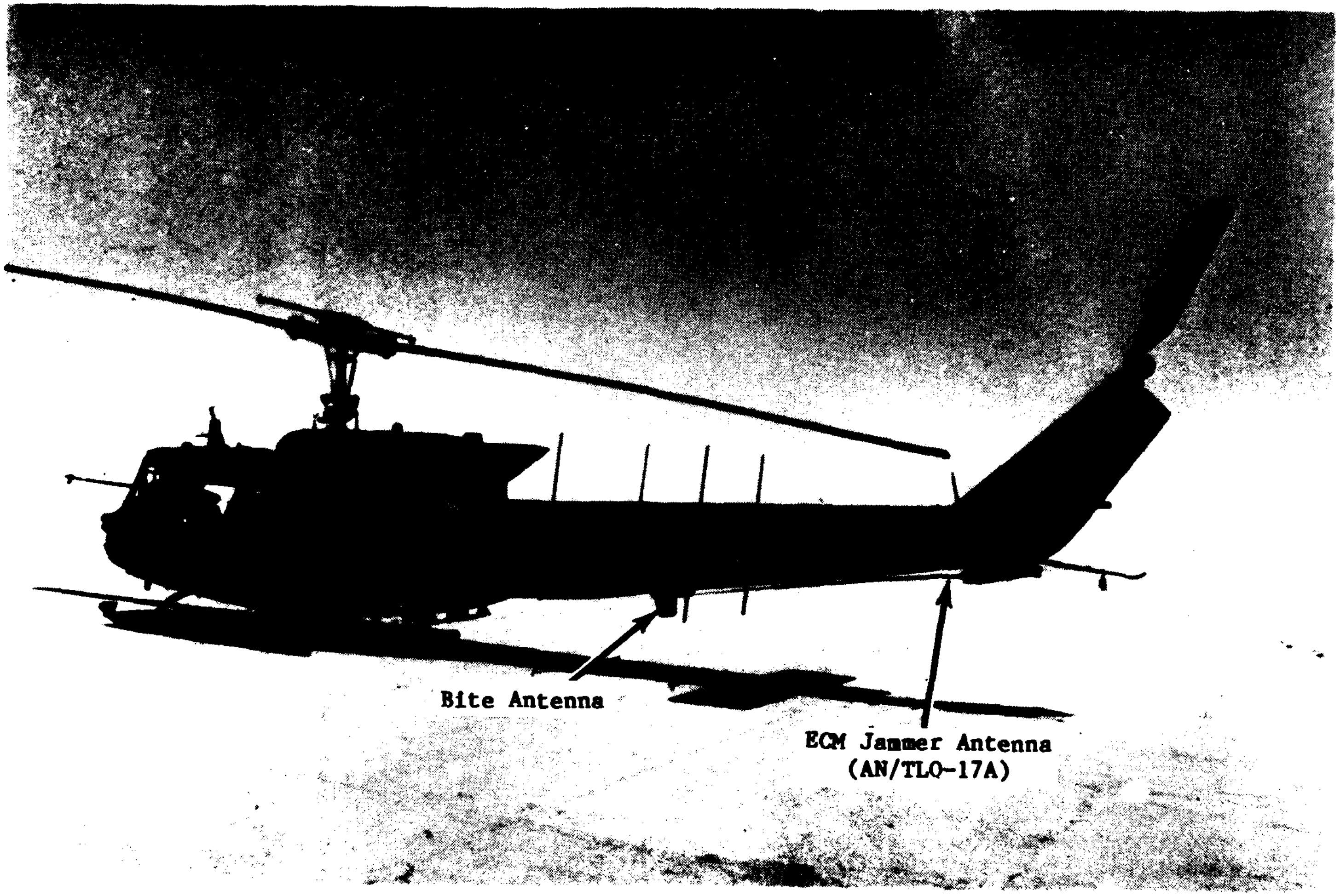


Photo 11. EH-1X(2) Aft Left Quartering view

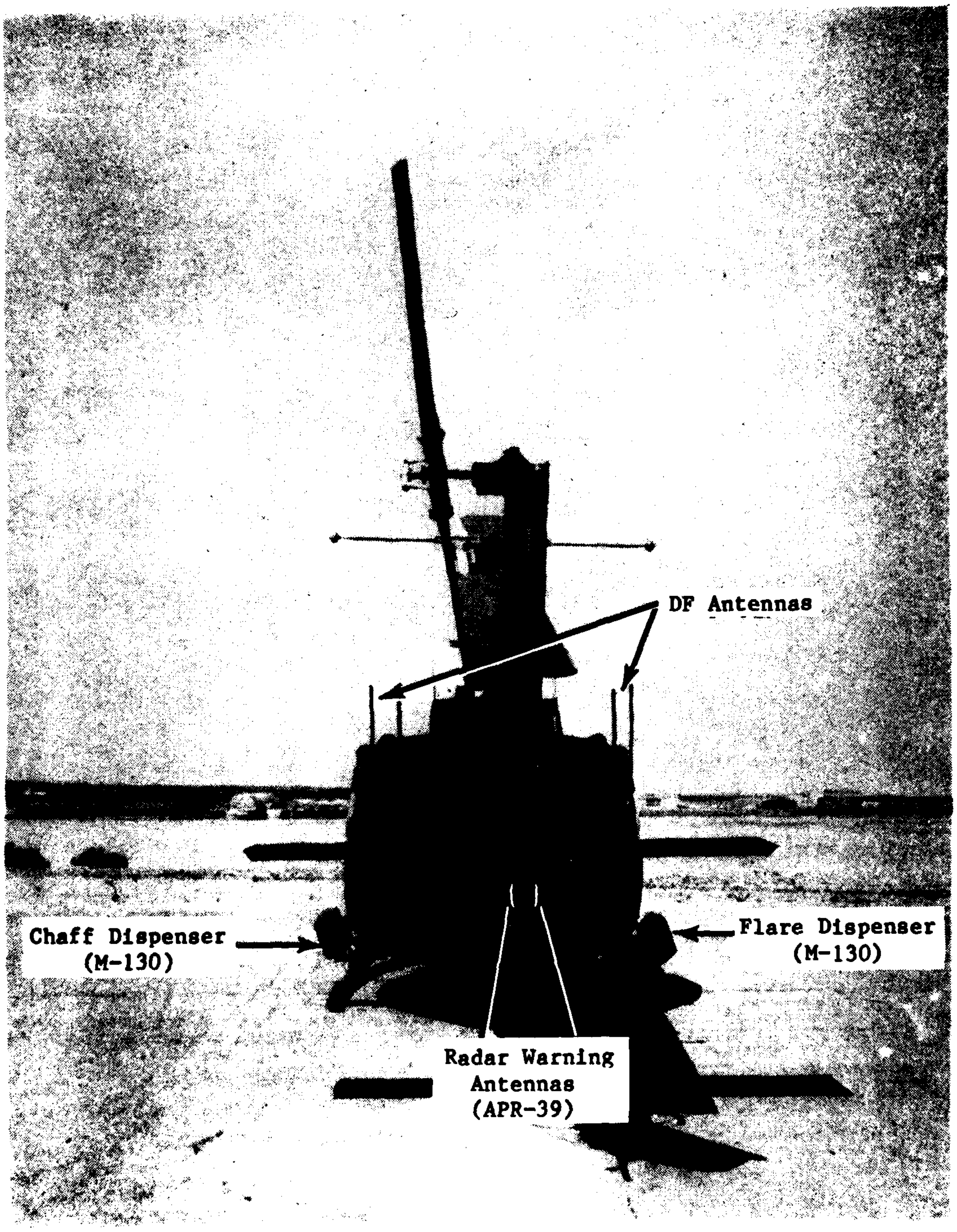


Photo 12. EH-1X(2) Rear View

Photo 13. AGPDS (M-130) Chaff Dispenser

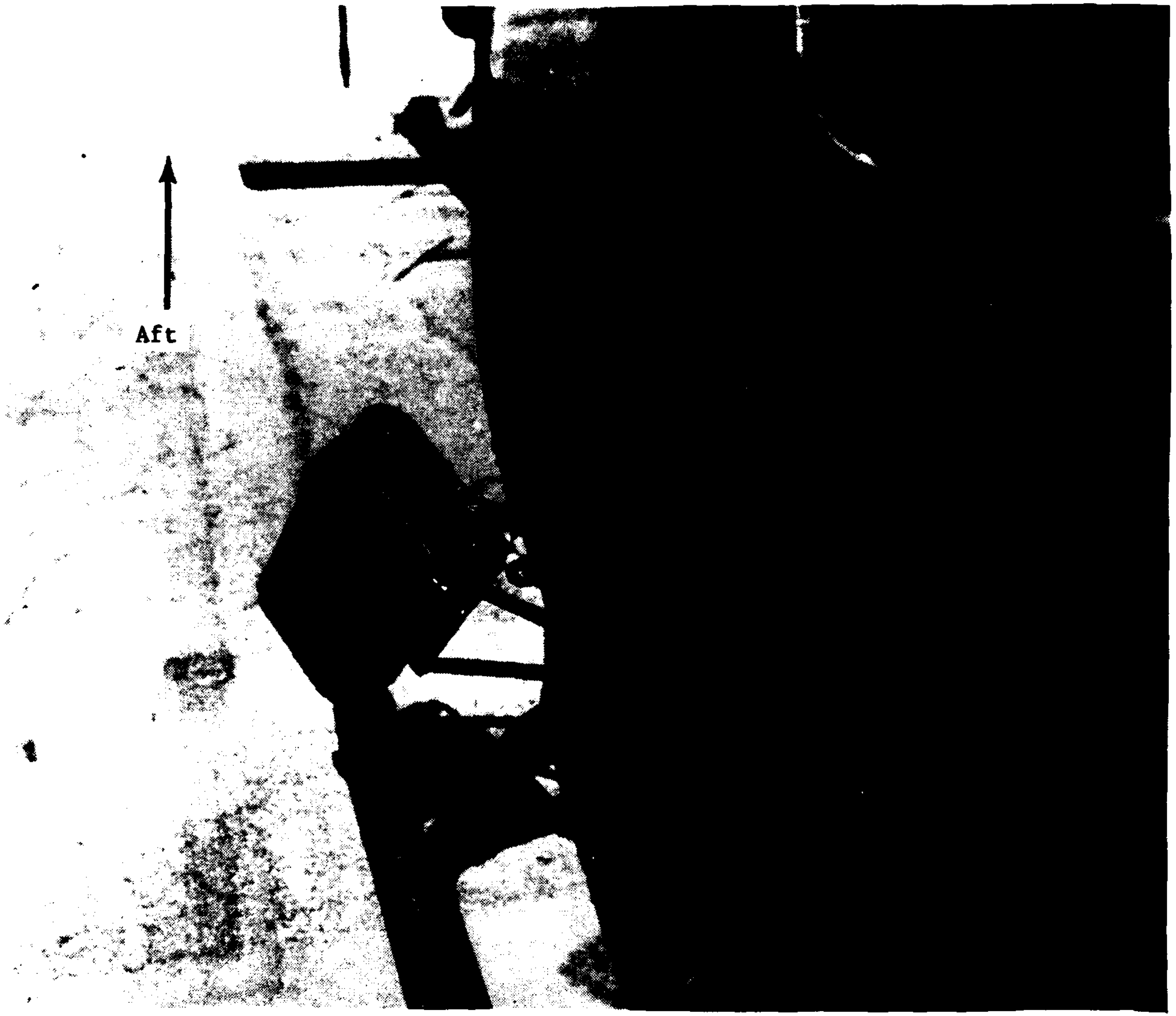


Photo 14. AGPDS (M-130) Flare Dispenser

Photo 15. EH-1X(3), Left Front Quartering View

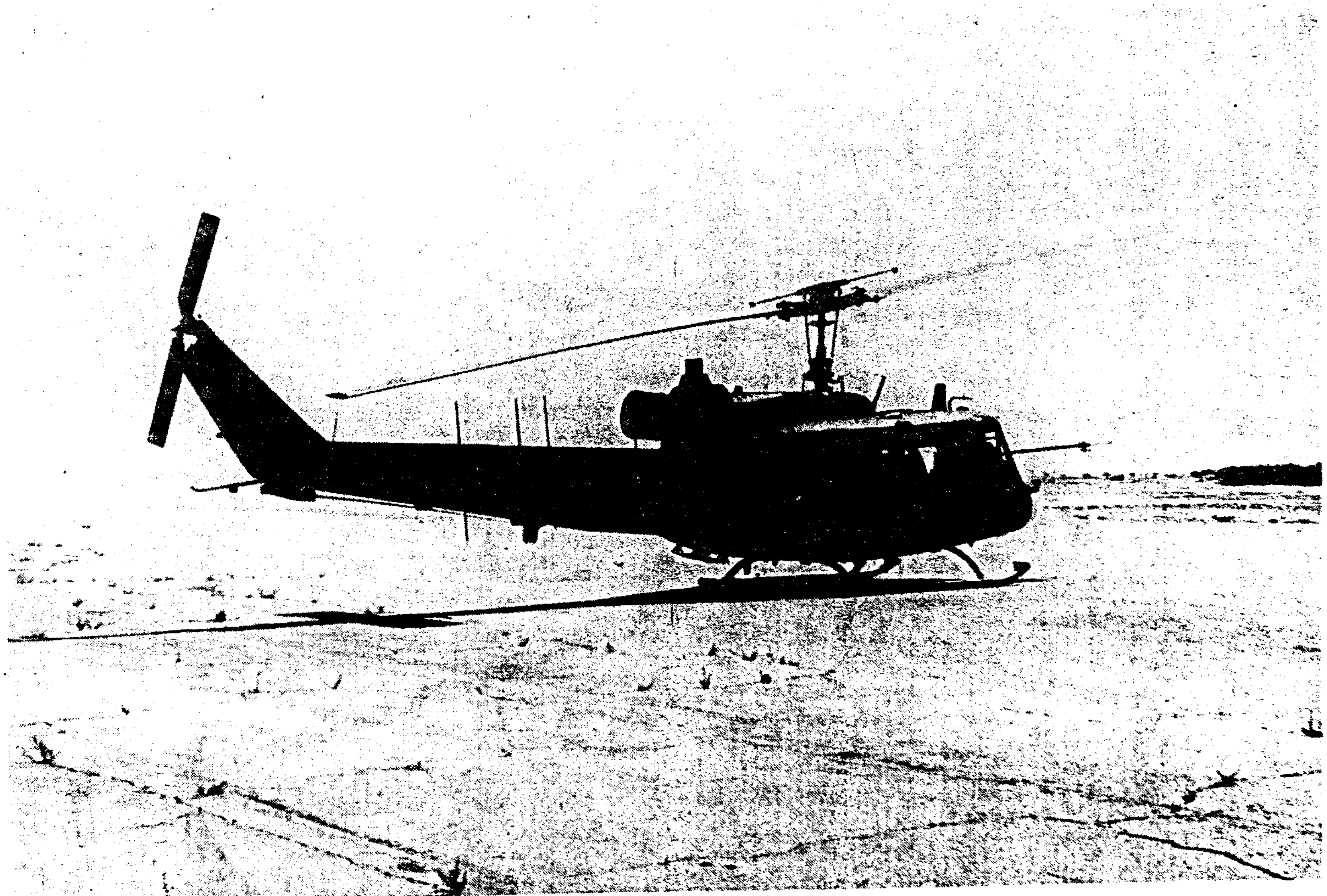


Photo 16. EH-1X(3), Right Rear Quartering View

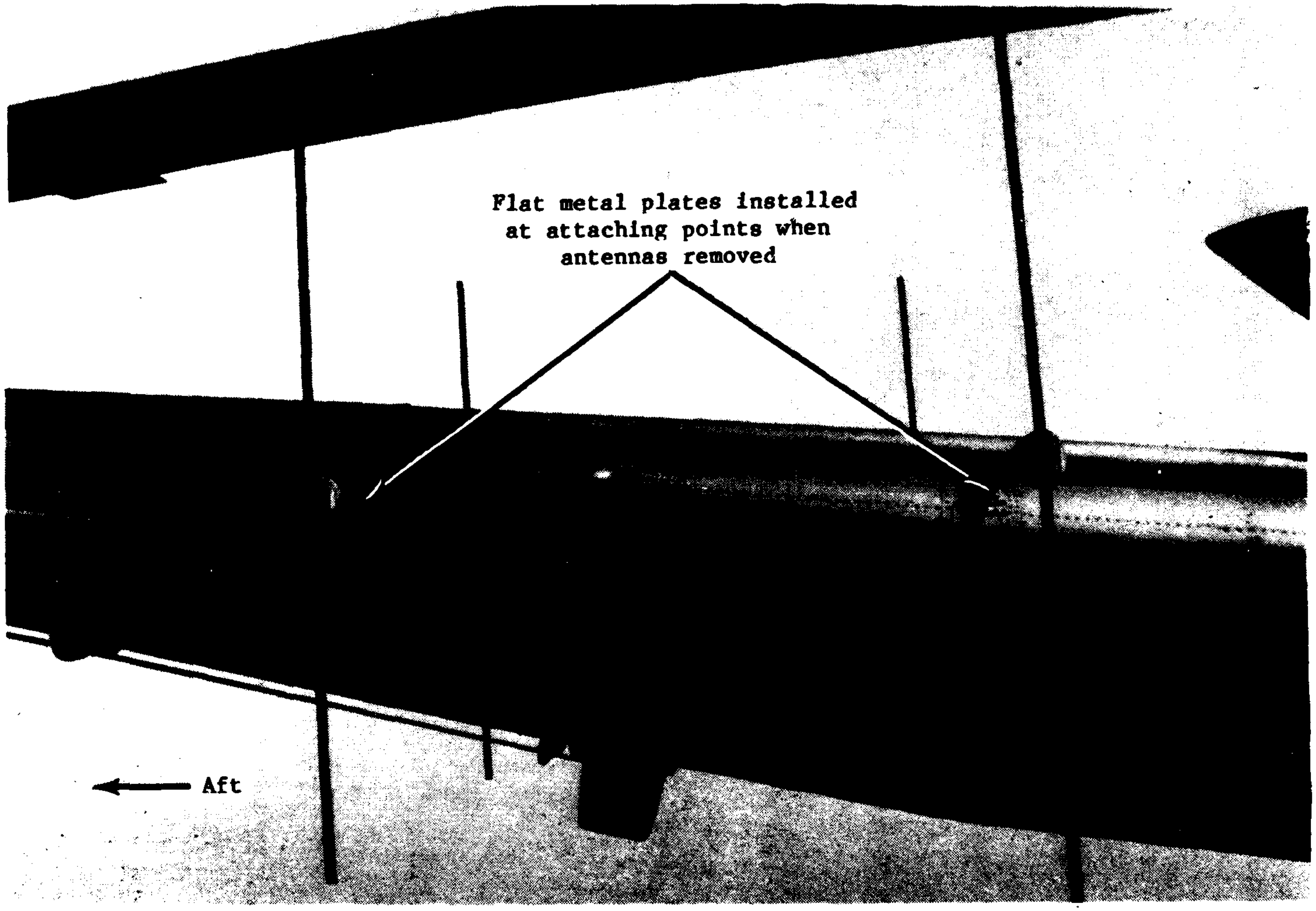


Photo 17. DF Antennas

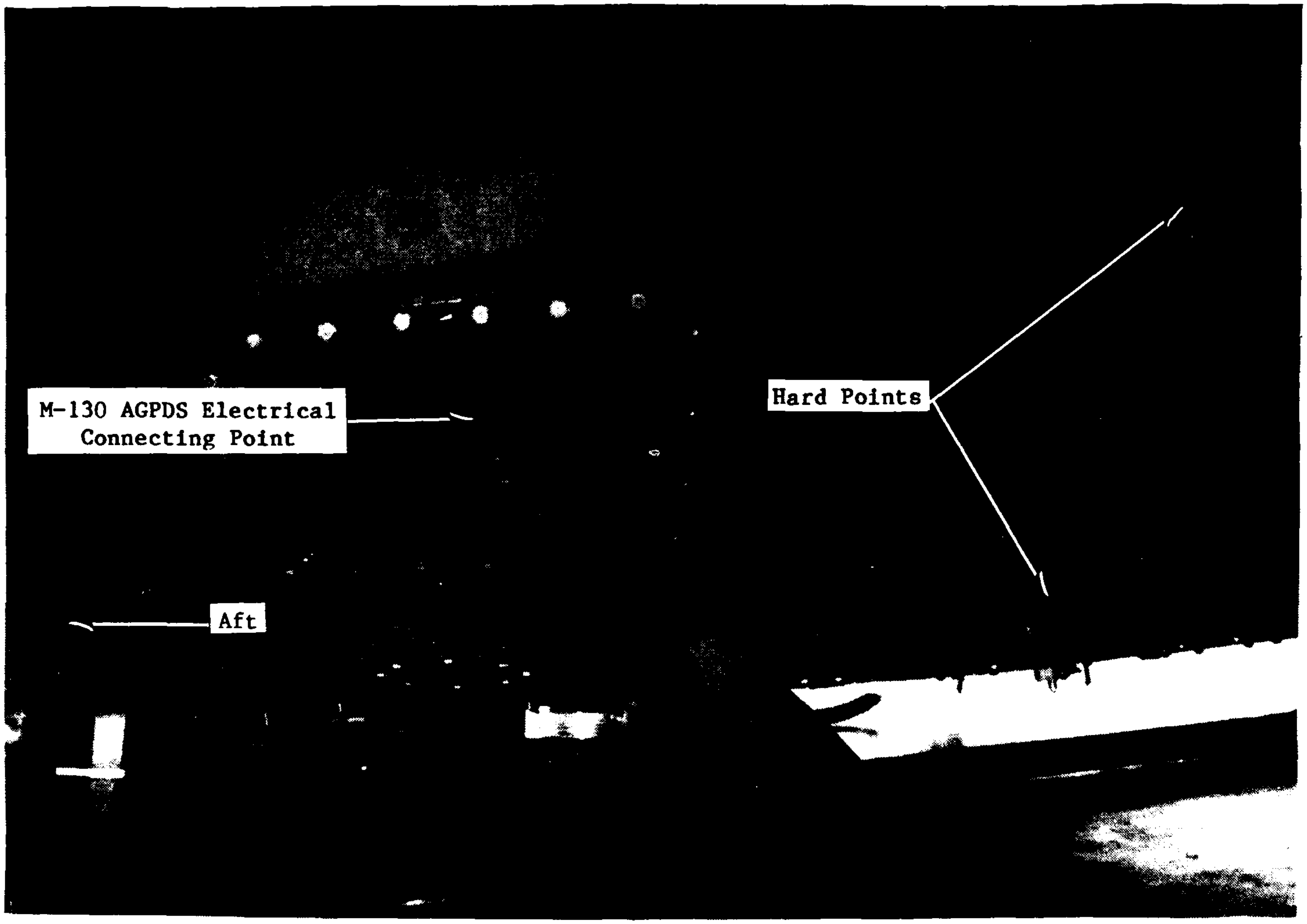


Photo 18. AGPDS (M-130) Mounting Hard Points

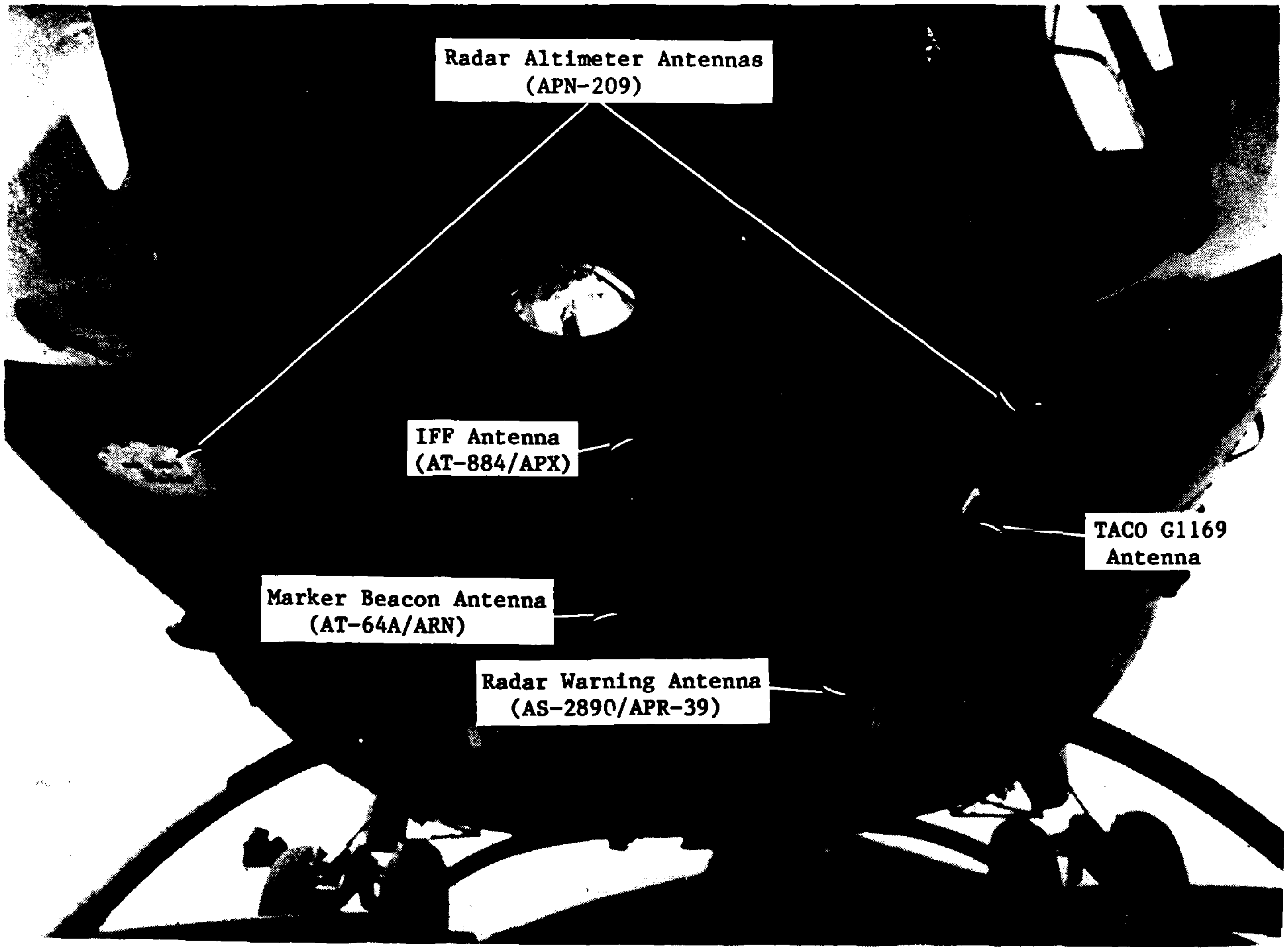


Photo 19. EH-1X Bottom-Front View

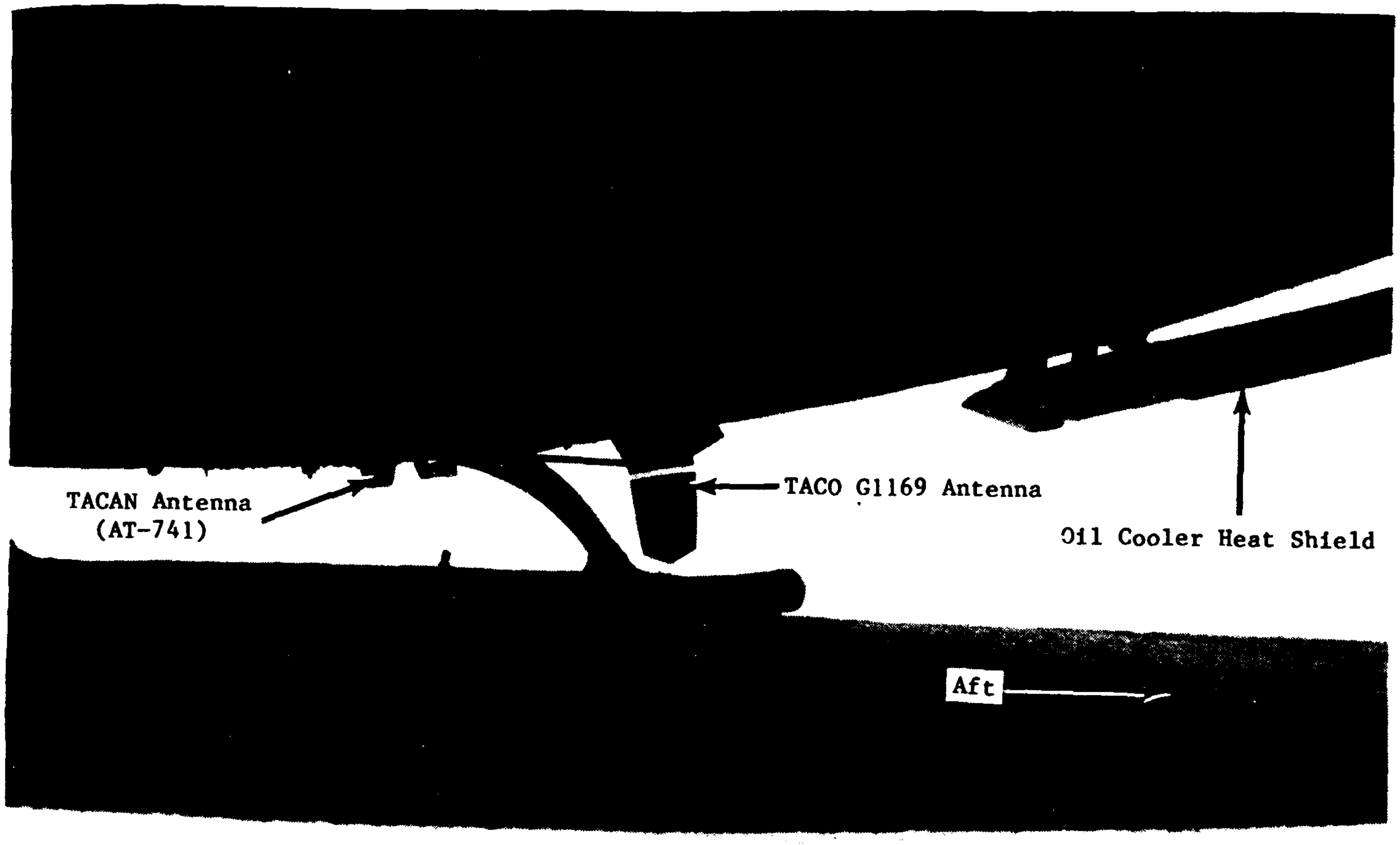


Photo 20. EH-1X Bottom-Left Quartering View

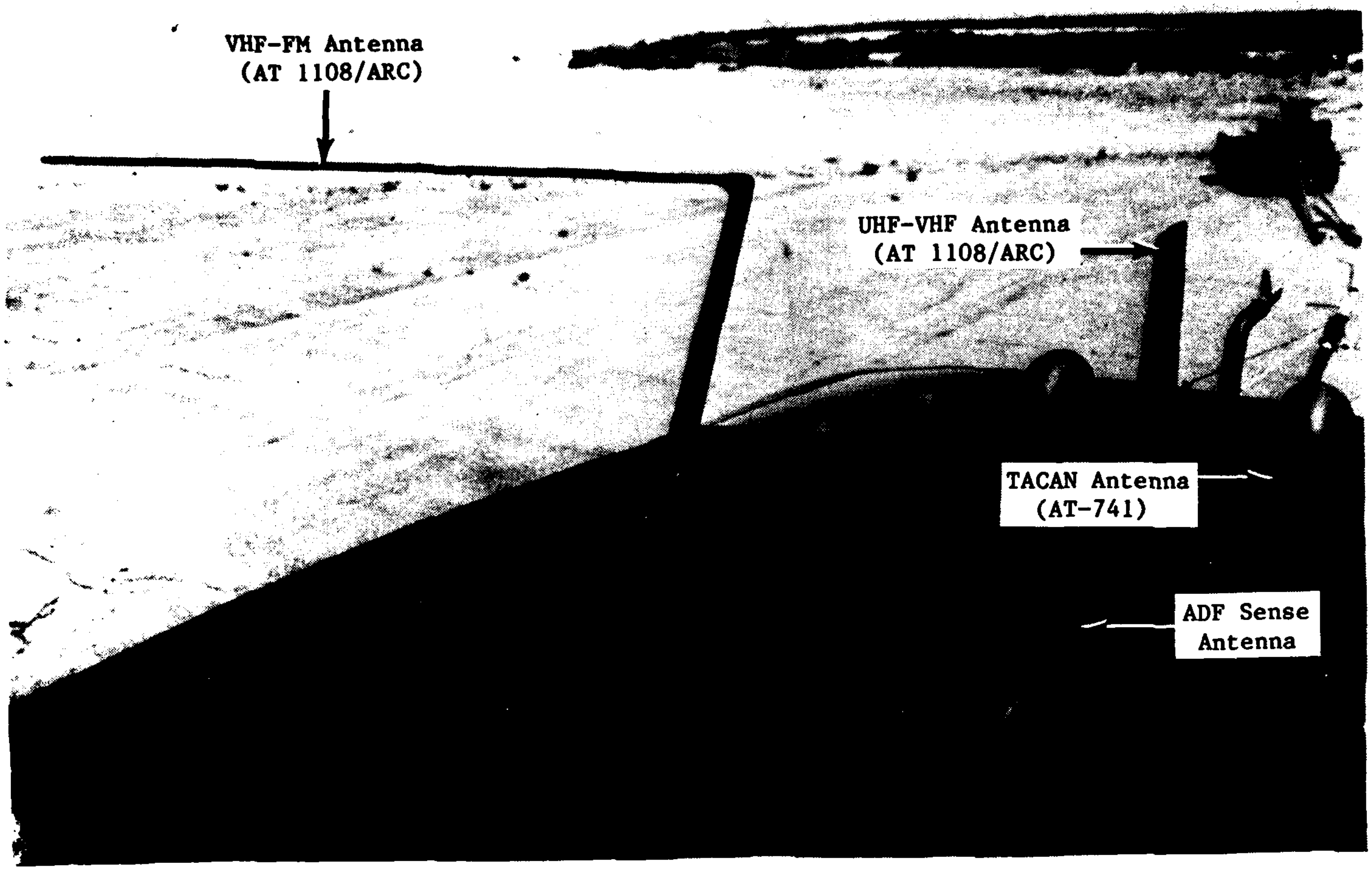


Photo 21. EX-1X Top-Forward Quartering View

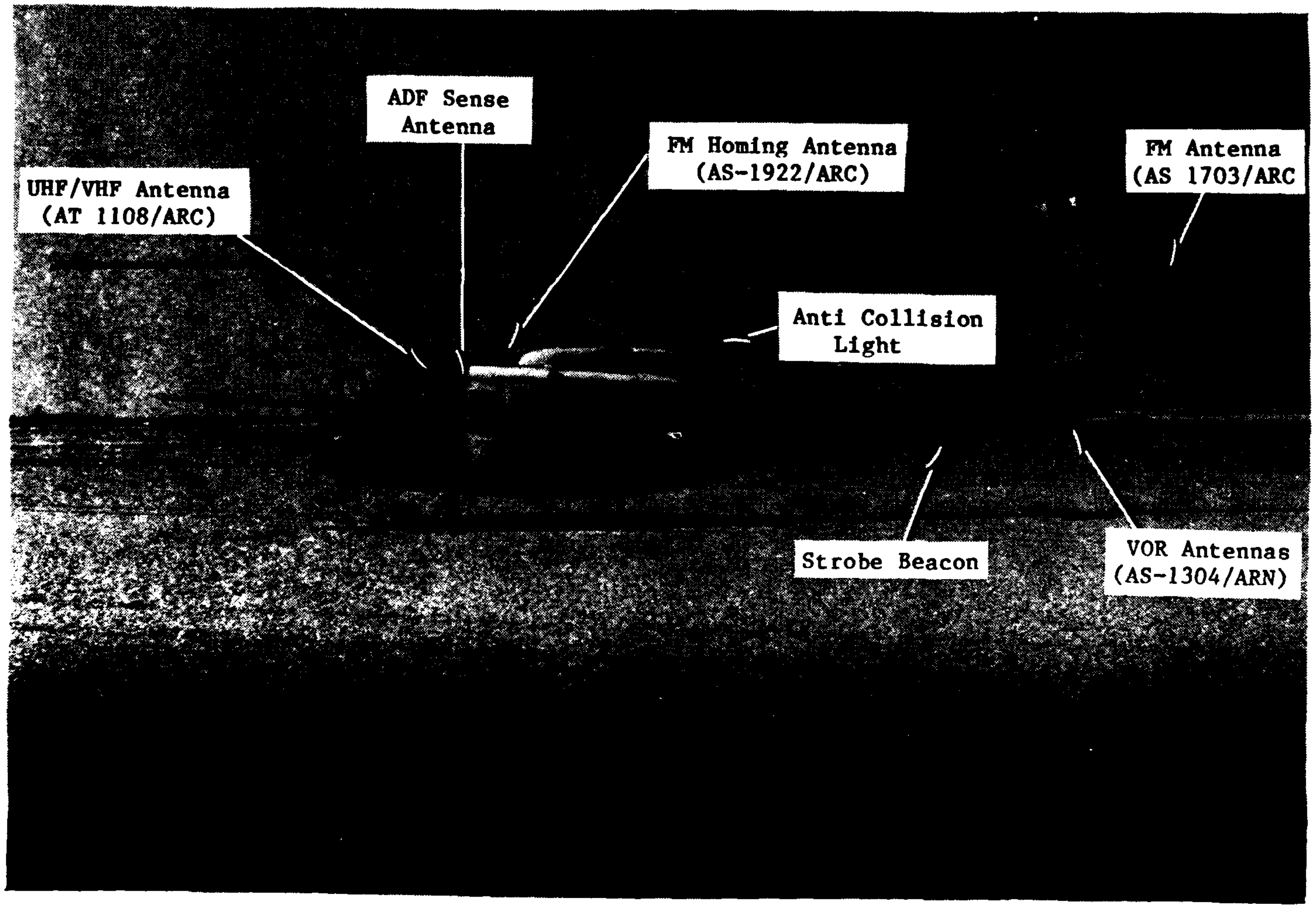


Photo 22. UH-1H Side View

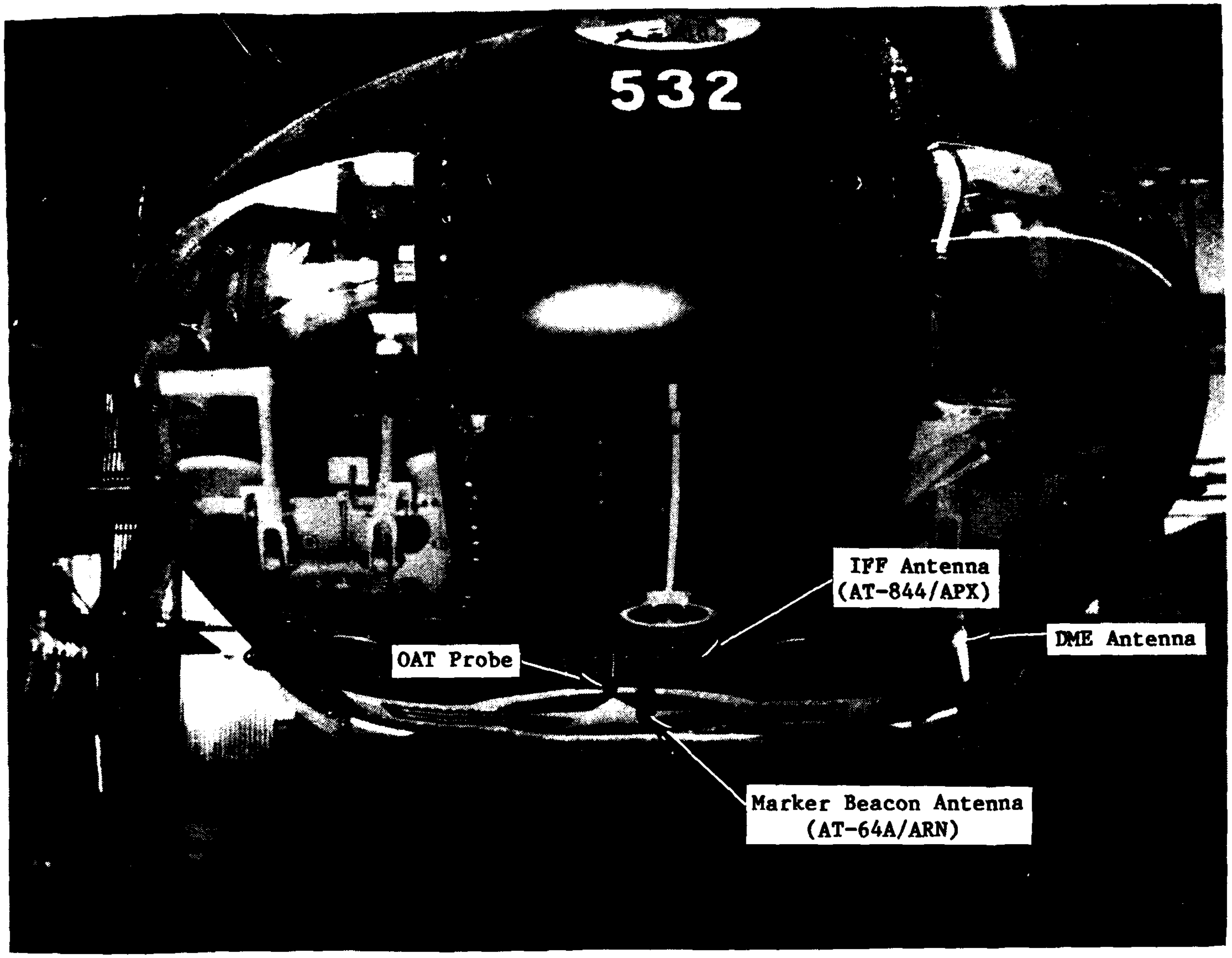


Photo 23. UH-1H Front-Bottom View

APPENDIX C. TEST INSTRUMENTATION

1. All instrumentation was calibrated and installed prior to commencing the test program. The engine test cell calibration is shown in figure 1. All quantitative data obtained during the flight test program were derived from special instrumentation. An instrumentation boom (photo 1) with a swiveling pitot-static tube was mounted on and extended 92 inches forward from the nose of the aircraft. The boom provided airspeed, altitude, free air temperature, and sideslip information. Instrument boom airspeed calibration is presented in figure 2. Engine torque was measured with a differential pressure transducer. A detailed tabulation of calibrated instrumentation, equipment and recorded data is listed below. Cockpit test instrumentation is shown in photo 2.

<u>Pilot Station</u>

Airspeed indicator (boom system)
Altitude indicator (boom system)
Sideslip Indicator (boom system)

<u>Copilot Station</u>

Airspeed indicator (boom system)
Altitude indicator (boom system)
Rotor speed indicator
Torque indicator
Free air temperature indicator (boom system)
Fuel counter (calibrated gauge with flow transducer)

<u>Hand Recorded Data</u>

Airspeed
Altitude
Fuel used
Free air temperature
Rotor speed
Engine torque pressure

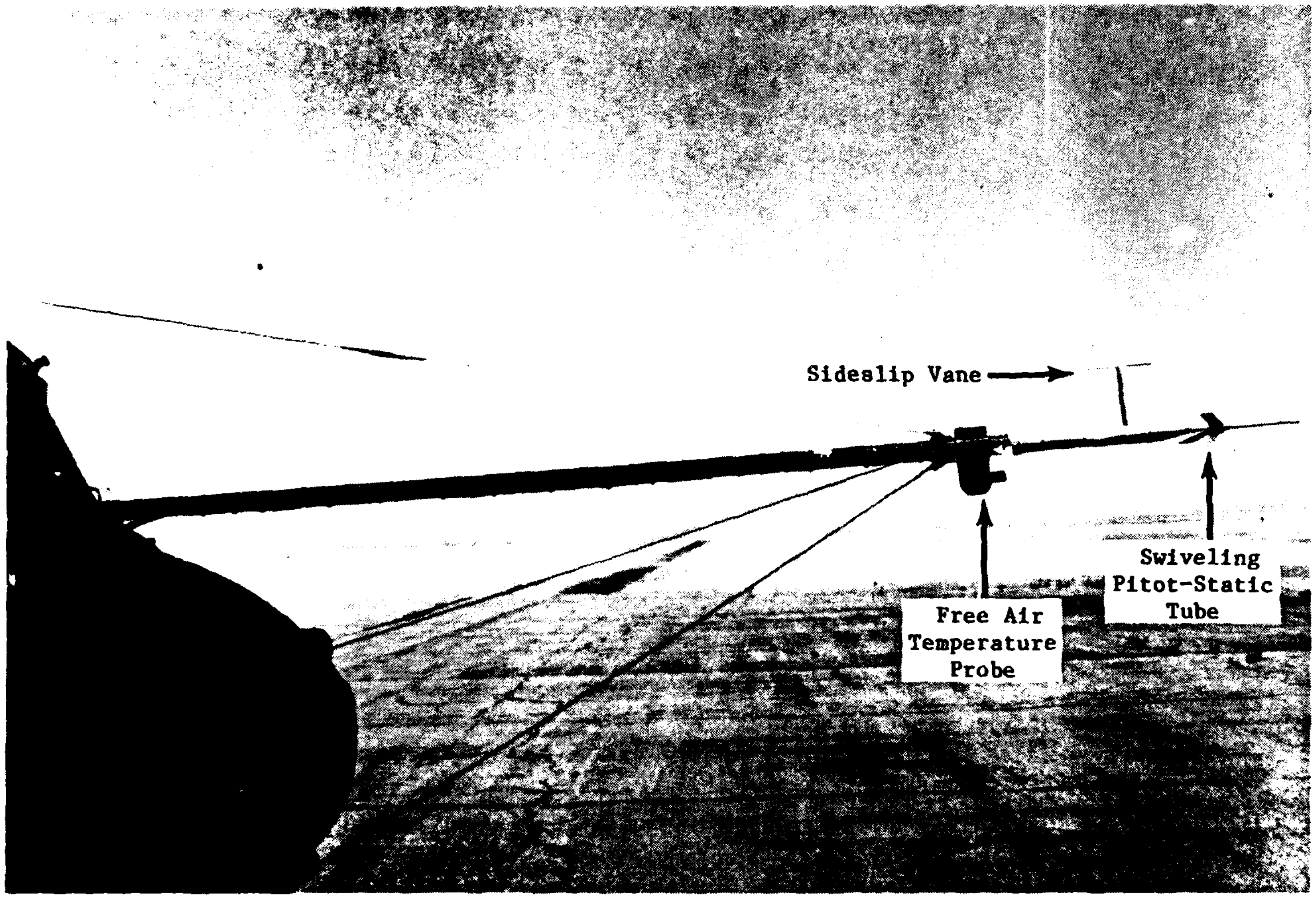


Photo 1. Test Instrumentation Boom

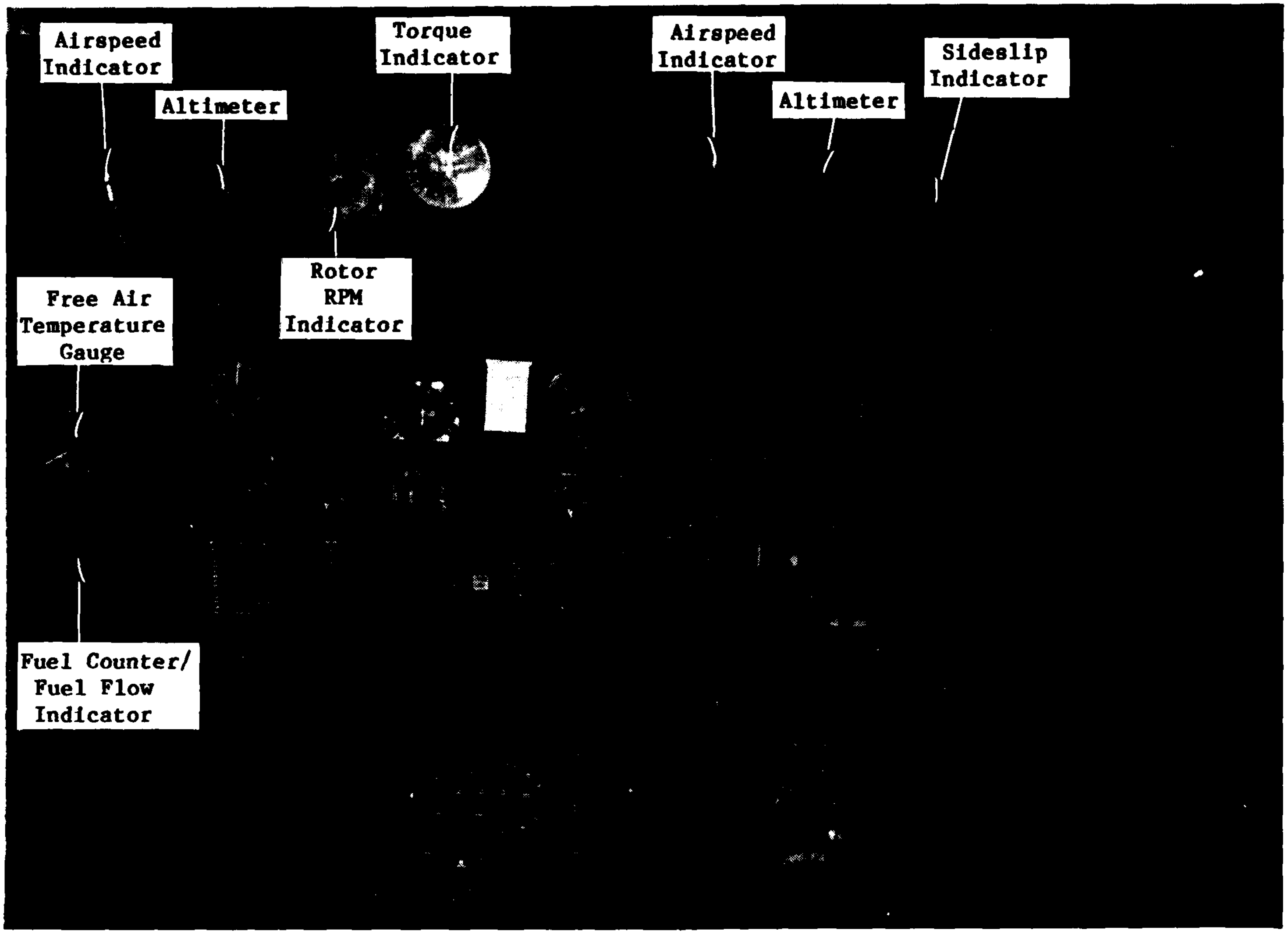


Photo 2. EH-1X Instrumentation Panel

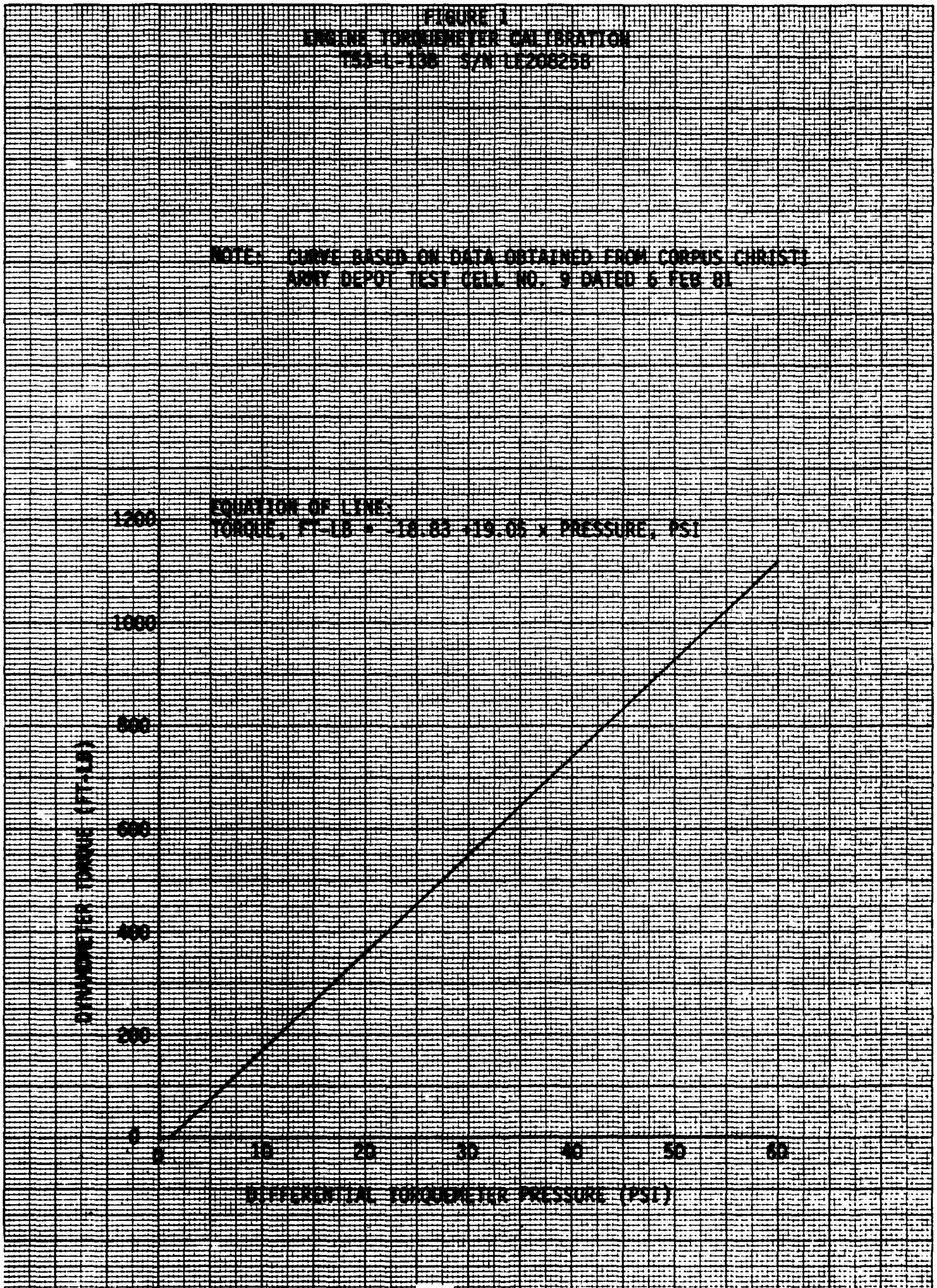


FIGURE 1
ENGINE TORQUEMETER CALIBRATION
T53-L-13B S/N LE20825B

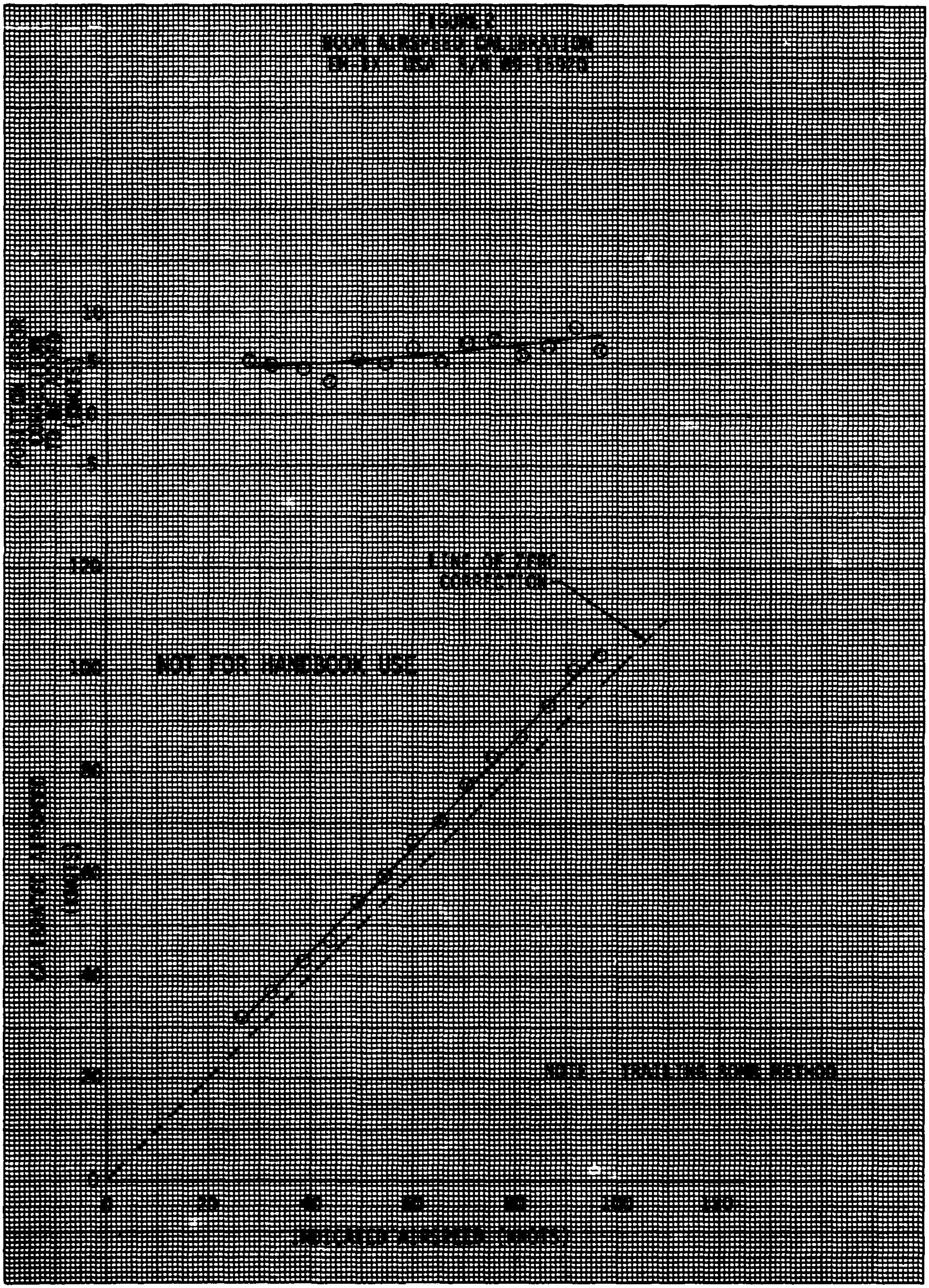


FIGURE 2
BOOM AIRSPEED CALIBRATION
LINE OF ZERO CORRECTION
NOT FOR HANDBOOK USE
INDICATED AIRSPEED (KNOTS)
0
20
40
60
80
100
120

APPENDIX D. TEST TECHNIQUES AND DATA ANALYSIS METHODS

GENERAL

1. Conventional level flight performance test techniques were used to conduct this evaluation. To achieve a constant thrust coefficient (C_T) throughout each test, a constant referred gross weight (the ratio of gross weight to pressure ratio, W/δ) and referred rotor speed (the ratio of rotor speed to square root of temperature ratio, $N_R/\sqrt{\theta}$) were maintained. A constant W/δ was maintained by increasing pressure altitude as the aircraft gross weight decreased due to fuel burnoff. Rotor speed was also varied to maintain a constant $N_R/\sqrt{\theta}$ as the ambient temperature varied. All tests were conducted in non-turbulent conditions to preclude atmospheric disturbances influencing the results. All tests were conducted with the ECM jammer antenna extended. Fifteen second records were taken manually at the mid point of approximately 1 minute stablized data points.

2. Three values of C_T were flown for five different configurations. The results of the level flight tests were converted to nondimensional form and plotted as power coefficient (C_P) versus C_T and constant airspeed ratio (μ). This plot defined the level flight performance for all gross weights, density altitudes, and airspeeds throughout the C_T range tested for the baseline configuration (EH-1X(1)).

WEIGHT AND BALANCE

3. The aircraft empty weight (including full oil and trapped fuel) and longitudinal center of gravity (cg) location were determined with a portable electronic weighing kit. Two complete weighings were conducted, one prior to the start of the test in the EH-1X (2) configuration, the other following the installation of the HMPP IR suppressor/IRCM jammer in the EH-1X(3) configuration.

4. A manometer-type external sight gauge was calibrated and used to determine fuel volume. Fuel specific gravity was measured with a hydrometer. The fuel loading for each test flight was determined both prior to engine start and following engine shutdown. Fuel used in flight was recorded manually from a test fuel used system and compared with the pre and post flight sight gauge readings. Fuel cg versus fuel volume contained in the fuel cell (208.5 gallon capacity) had been previously determined. This calibration was used to calculate aircraft cg for each test point. Aircraft engine start gross weight and cg were also controlled by ballast installed in the aircraft.

Level Flight Performance

5. The level flight performance data were generalized by the following nondimensional coefficients:

a. Coefficient of power (C_P):

$$C_P = \frac{SHP\ (550)}{\rho A(\Omega R)^3} \tag{1}$$

b. Coefficient of thrust (C_T):

$$C_T = \frac{Thrust}{\rho A(\Omega R)^2} \tag{2}$$

c. Advance ratio (μ):

$$\mu = \frac{(1.68781)V_T}{\Omega R} \tag{3}$$

d. Advancing blade tip Mach number (M_{tip}):

$$M_{tip} = \frac{(1.68781)V_T + (\Omega R)}{a} \tag{4}$$

where:

SHP = Engine output shaft horsepower
550 = Conversion factor (ft-lb/sec/SHP)
ρ = Air density (slug/ft^3)
A = Main rotor disc area (ft^2) = 1809.5
Ω = Main rotor angular velocity (radians/sec = 33.93 at 324 RPM)
R = Main rotor radius (ft) = 24.0
Thrust = Gross weight (lb) during free flight in which there is no acceleration component in the vertical direction.
1.68781 = Conversion factor (ft/sec/knot)
V_T = True airspeed (knot) = (calibrated airspeed/$\sqrt{\sigma}$)
σ = Density ratio = ρ/ρ_o = δ/θ
ρ_o = air density at sea level standard day (slug/ft^3) = 0.002376892

$\delta = [1-(6.875586 \times 10^{-6})\ H_p]^{5.255863}$
H_p = Pressure altitude (ft)
$\theta = (T + 273.15)/288.15$
T = ambient air temperature (°C)
a = Speed of sound (ft/sec) = $1116.45\sqrt{\theta}$

For normal operating rotor speed of 324 rpm the following constants were used:

$A = 1809.5\ ft^2$
$\Omega R = 814.30$ ft/sec
$A(\Omega R)^2 = 1.199851385 \times 10^9\ ft^4/sec^2$
$A(\Omega R)^3 = 9.770389825 \times 10^{11}\ ft^5/sec^3$

Test day (measured) level flight power was corrected to average flight conditions for each set of speed power data by assuming the test day dimensionless parameters C_{P_t}, C_{T_t}, and μ_t are identical to $C_{P_{avg}}$ and $C_{T_{avg}}$, and μ_{avg} respectively.

From equation 1, the following relationship can be derived:

$$SHP_{avg} = (0.12414)\ (C_{P_T})\ (\sigma_{avg})\ (N_{R_{avg}})^3 \qquad (5)$$

where:

N_R = rotor speed (rpm)
subscript avg - average over each set of speed power data

Shaft Horsepower Required

6. The engine output shaft torque was determined from the engine manufacturer's torque system. The relationship of measured torque pressure (PSI) to engine output shaft torque (ft-lb) was determined from the engine test cell calibration shown in figure 1, appendix C. The output shp was determined from the engine output shaft torque and rotational speed by the equation below.

$$SHP = \frac{2\pi \times N_P \times Q}{33{,}000} \qquad (6)$$

where:

N_p = Engine output shaft rotational speed (rpm)
Q = Engine output shaft torque (ft-lb)
33,000 = Conversion factor (ft-lb/min/SHP)

Airspeed Calibration

7. The boom pitot-static system was calibrated by using the trailing bomb method to determine the airspeed position error, presented in figure 2, appendix C. Calibrated airspeed (V_{cal}) was obtained by correcting the bomb indicated airspeed (V_i) using instrument (ΔV_{ic}) and position (ΔV_{pc}) error corrections.

$$V_{cal} = V_{i_{bomb}} + \Delta V_{ic_{bomb}} + \Delta V_{pc_{bomb}} \quad (7)$$

The airspeed position error (correction to be added) was determined by:

$$\Delta V_{pc_{boom}} = V_{cal} - (V_{i_{boom}} + \Delta V_{ic_{boom}}) \quad (8)$$

Drag

8. The following relationships were used to compute differential drag in terms of a change in equivalent flat plate area (ΔF_e).

$$\Delta F_e = 2A\ \Delta C_P/\mu^3 = \frac{(228.782)\ (\Delta SHP)}{\rho V_T{}^3} \quad (9)$$

where:

ΔC_P = differential power coefficient (based on engine power)
ΔSHP = Differential output shaft horsepower

NOTE: No corrections were made for airspeed boom drag.

APPENDIX E. TEST DATA

INDEX

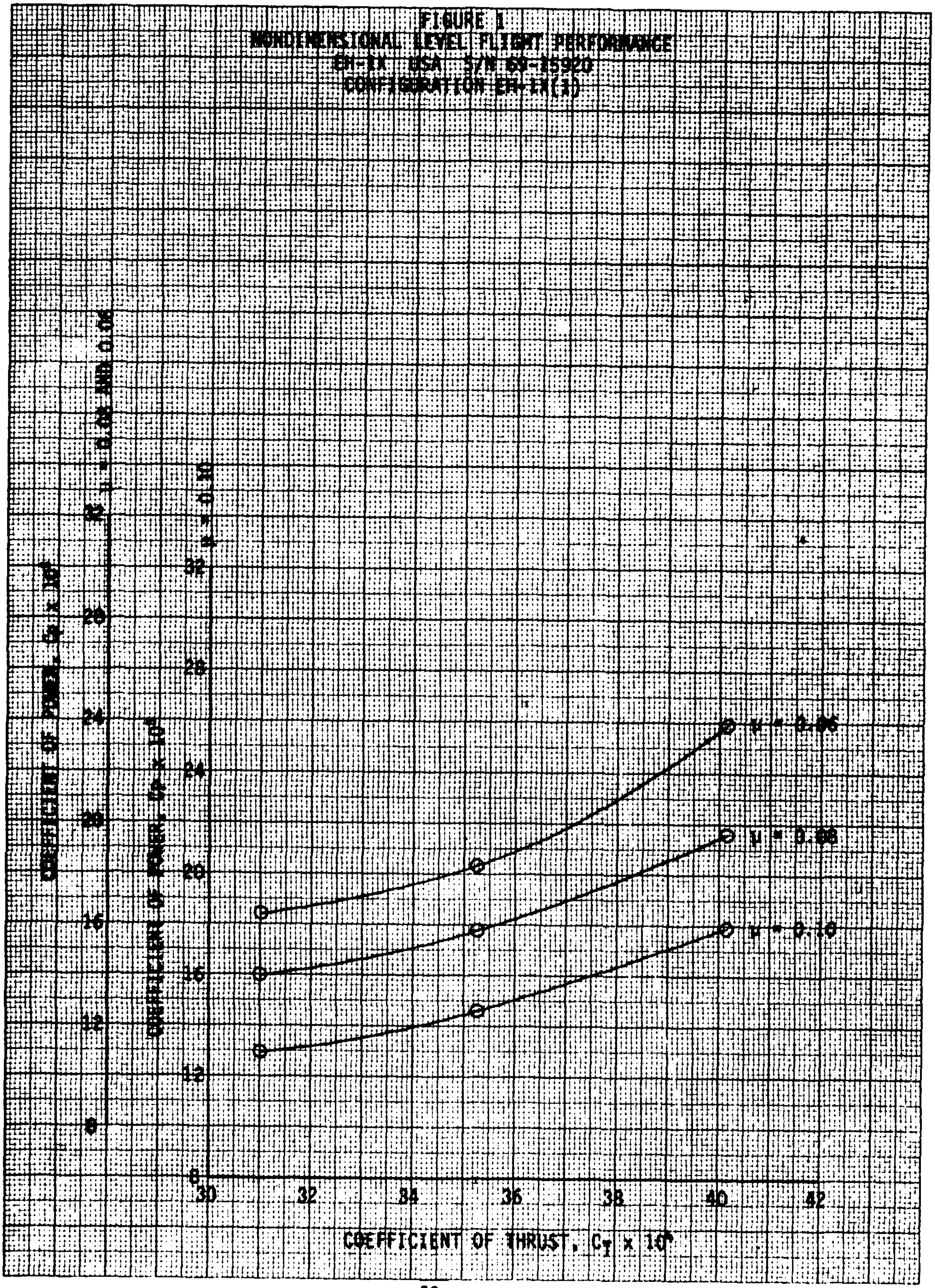
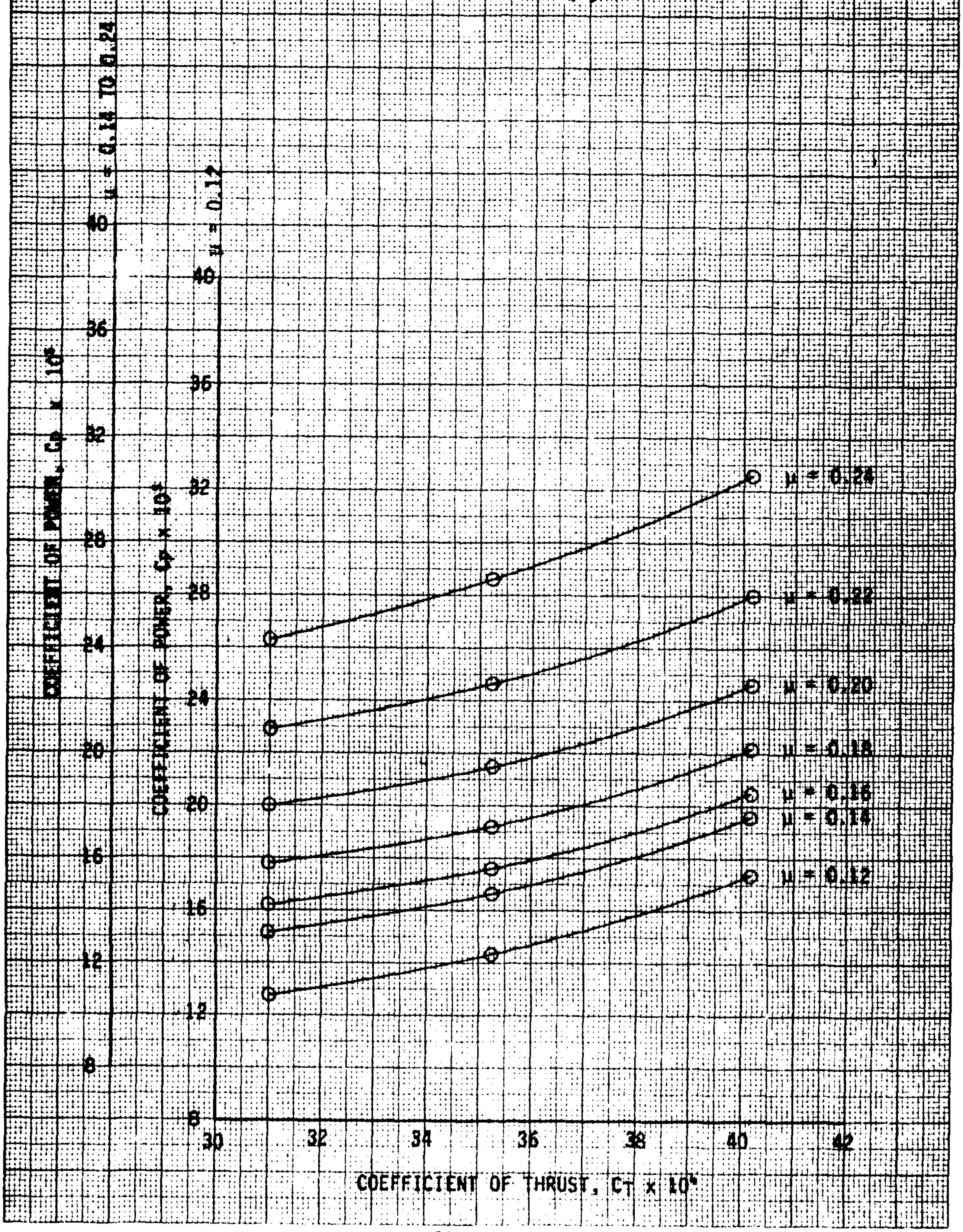


FIGURE 1
NONDIMENSIONAL LEVEL FLIGHT PERFORMANCE
EH-1X USA S/N 69-15920
CONFIGURATION EH-1X(1)
COEFFICIENT OF POWER, $C_P \times 10^6$
COEFFICIENT OF THRUST, $C_T \times 10^4$
μ = 0.06
μ = 0.08
μ = 0.10

FIGURE 2
NONDIMENSIONAL LEVEL FLIGHT PERFORMANCE
EH-1X USA S/N 69-15920
CONFIGURATION EH-1X(1)



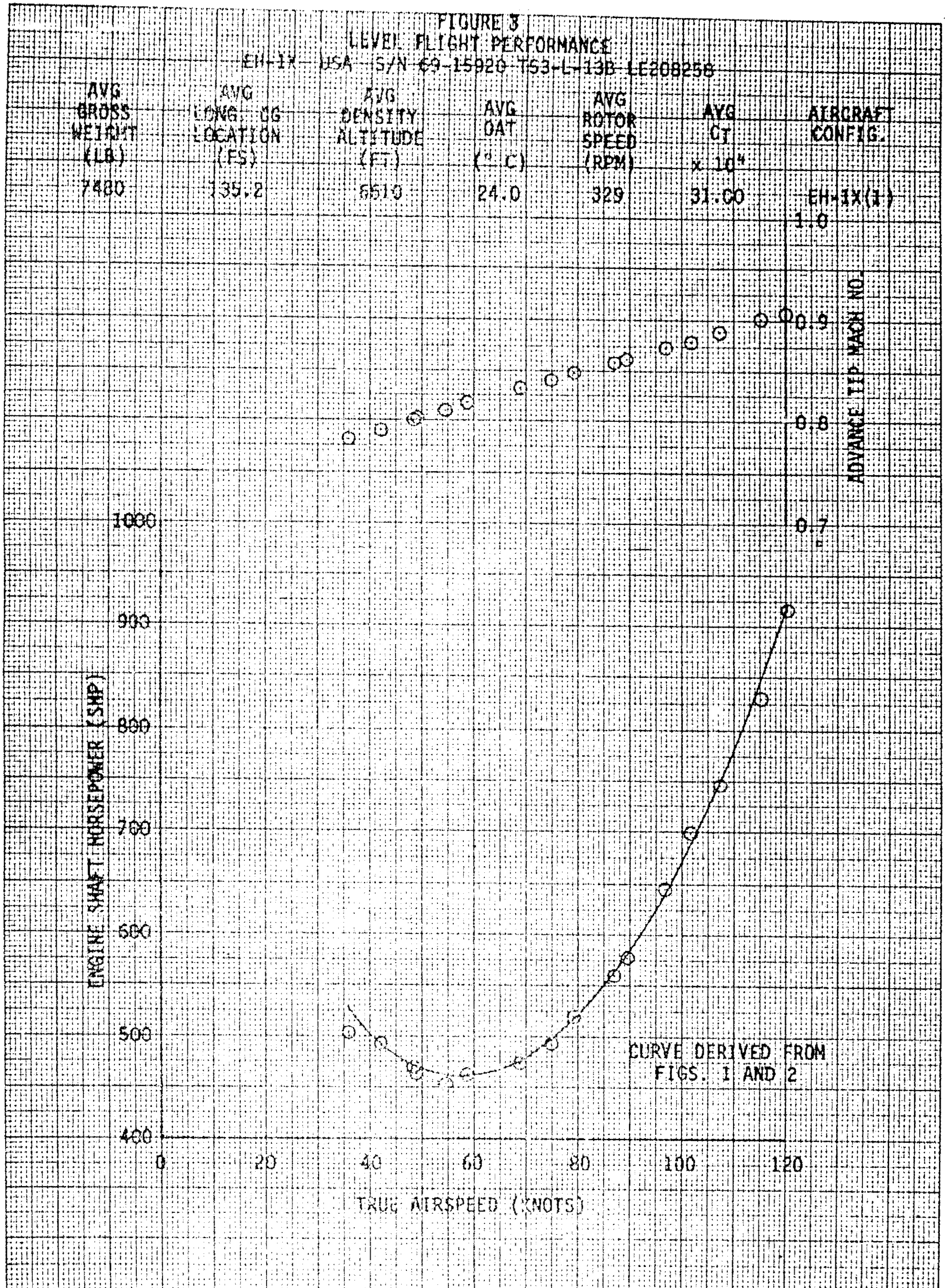


FIGURE 3
LEVEL FLIGHT PERFORMANCE
EH-1X USA S/N 69-15920 T53-L-13B LE208258
AVG GROSS WEIGHT (LB)
7480
AVG LONG. CG LOCATION (FS)
135.2
AVG DENSITY ALTITUDE (FT)
6510
AVG OAT (° C)
24.0
AVG ROTOR SPEED (RPM)
329
AVG CT x 10⁴
31.00
AIRCRAFT CONFIG.
EH-1X(1)
ADVANCE TIP MACH NO.
1.0
0.9
0.8
0.7
ENGINE SHAFT HORSEPOWER (SHP)
1000
900
800
700
600
500
400
0
20
40
60
80
100
120
TRUE AIRSPEED (KNOTS)
CURVE DERIVED FROM FIGS. 1 AND 2

FIGURE 4
LEVEL FLIGHT PERFORMANCE
EH-1X USA S/N 69-15920 T53-L-13B LE208258

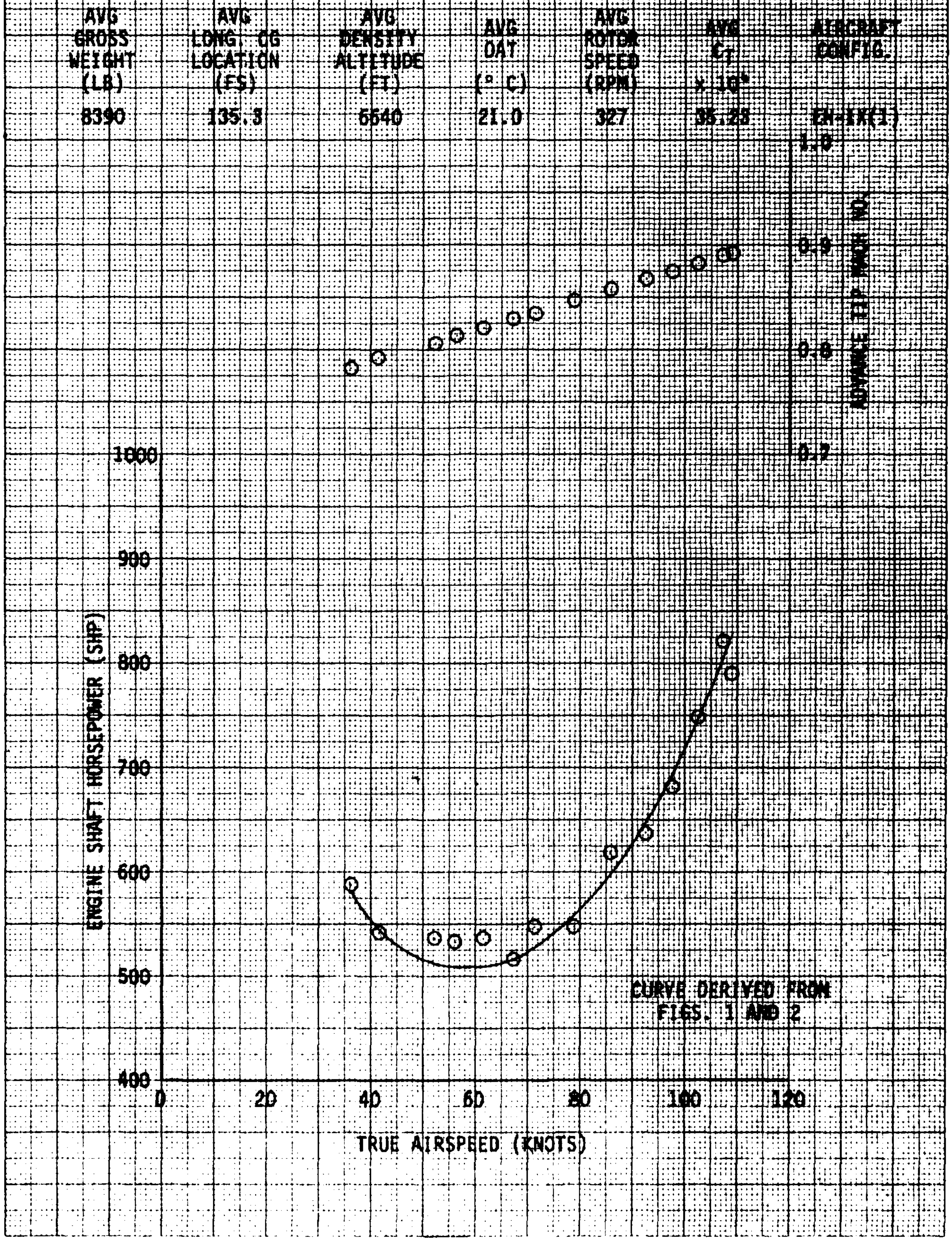


FIGURE 5
LEVEL FLIGHT PERFORMANCE
EH-1X USA S/N 69-15920 T53-L-13B LE208258

AVG GROSS WEIGHT (LB)	AVG LONG. CG LOCATION (FS)	AVG DENSITY ALTITUDE (FT)	AVG OAT (° C)	AVG ROTOR SPEED (RPM)	AVG CT $\times 10^4$	AIRCRAFT CONFIG.
8320	135.9	10,540	15.0	324	40.18	EH-1X(I) 1.0

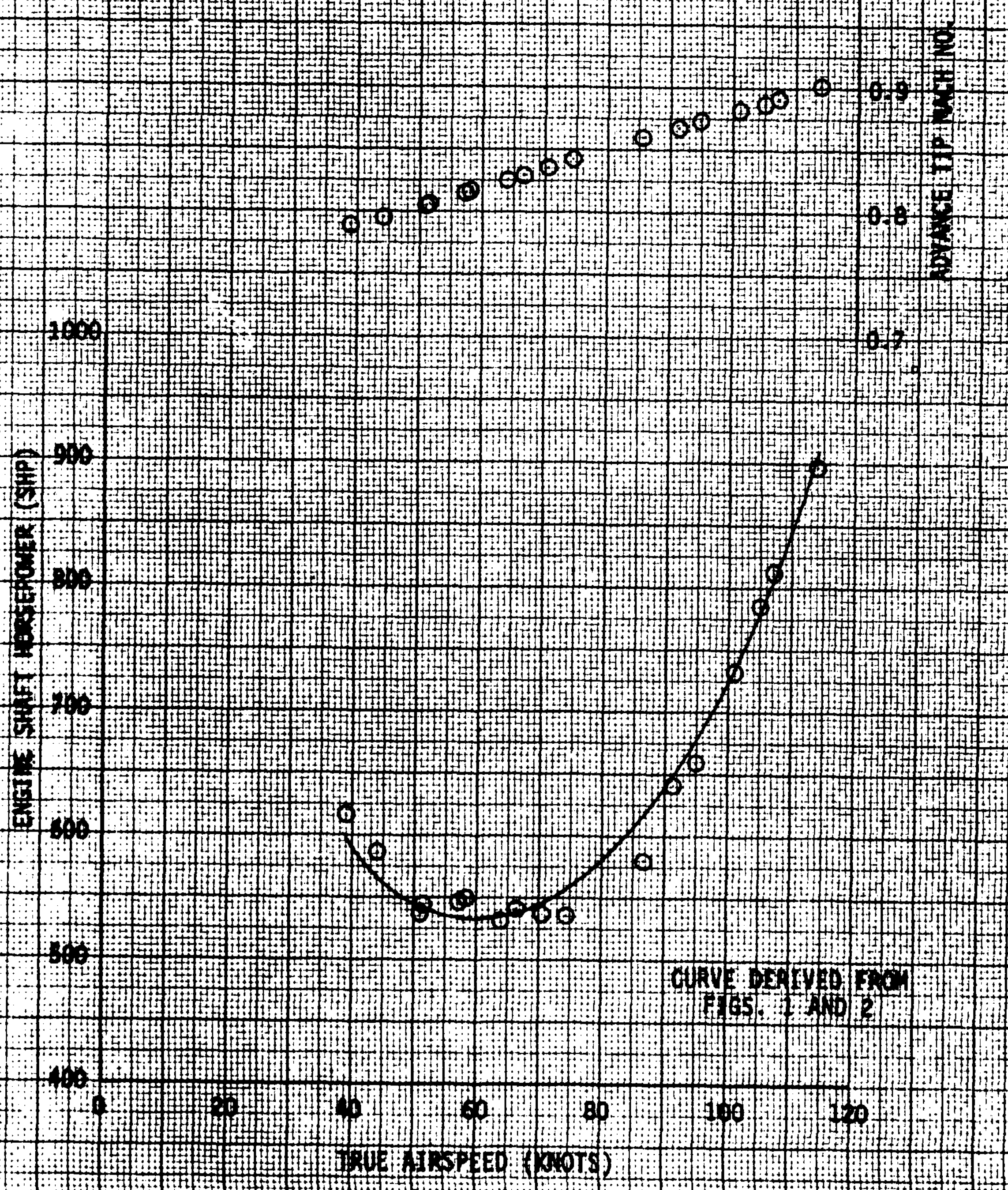
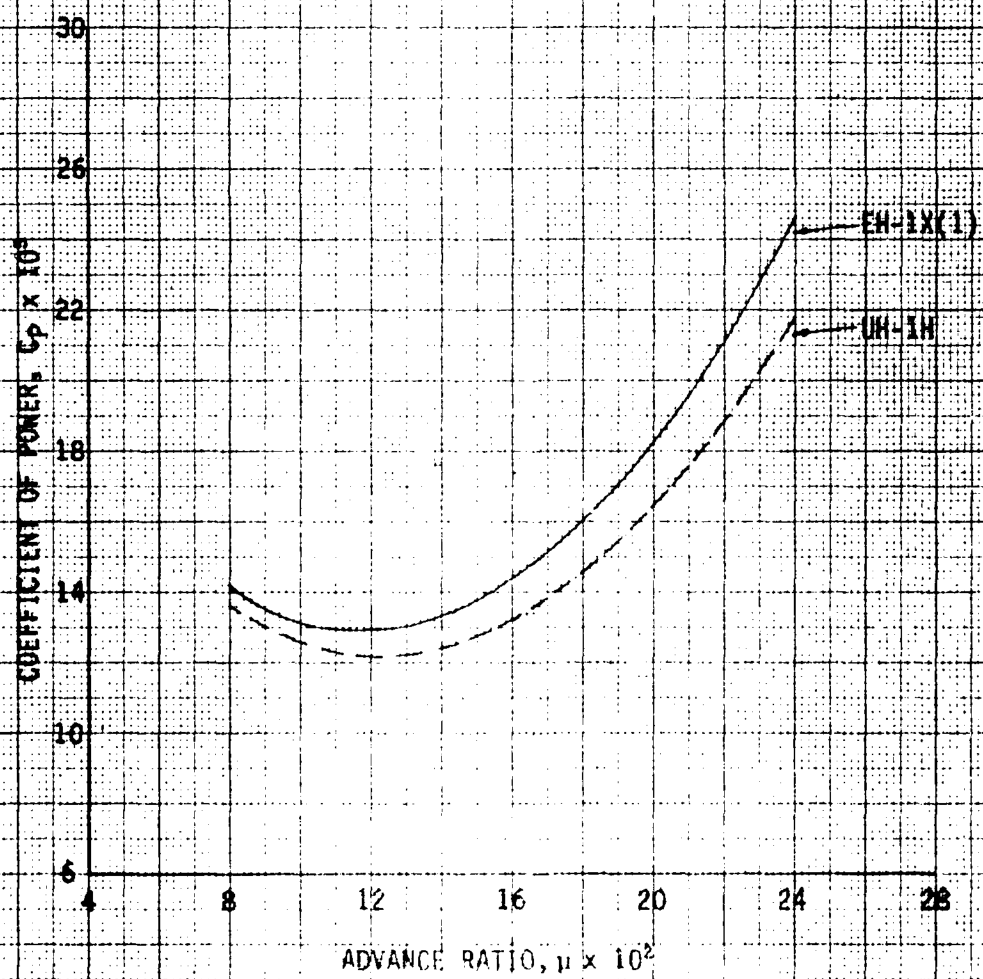


FIGURE 6
NONDIMENSIONAL LEVEL FLIGHT PERFORMANCE
EH-1X(1) VERSUS UH-1H
$C_T = 0.003167$



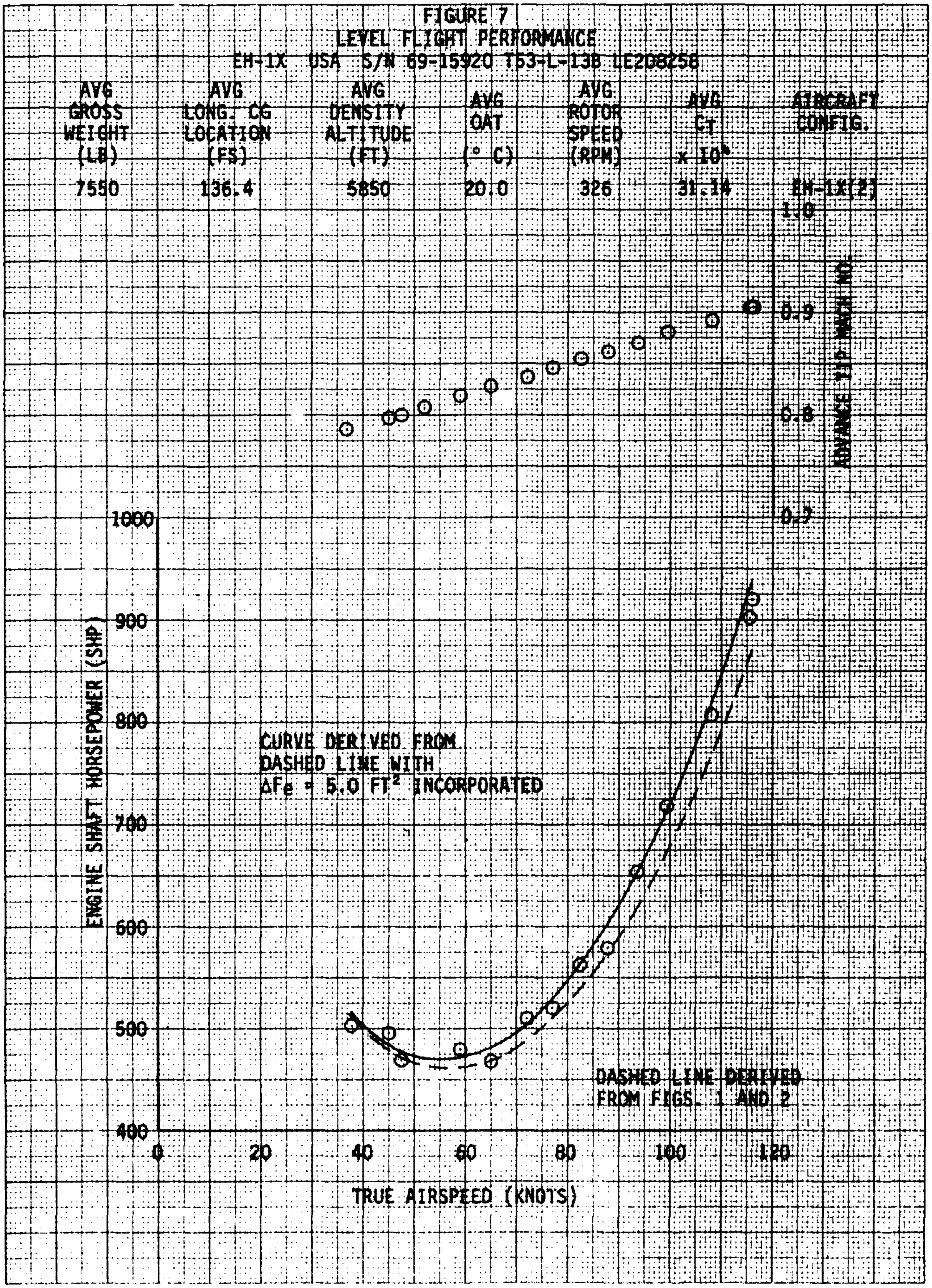


FIGURE 7
LEVEL FLIGHT PERFORMANCE
EH-1X USA S/N 69-15920 T53-L-13B LE208258
AVG GROSS WEIGHT (LB) 7550
AVG LONG. CG LOCATION (FS) 136.4
AVG DENSITY ALTITUDE (FT) 5850
AVG OAT (° C) 20.0
AVG ROTOR SPEED (RPM) 326
AVG C_T x 10^4 31.14
AIRCRAFT CONFIG. EH-1X(2)
1.0
0.9
0.8
0.7
ADVANCE TIP MACH NO.
1000
900
800
700
600
500
400
ENGINE SHAFT HORSEPOWER (SHP)
CURVE DERIVED FROM
DASHED LINE WITH
ΔFe = 5.0 FT² INCORPORATED
DASHED LINE DERIVED
FROM FIGS. 1 AND 2
0
20
40
60
80
100
120
TRUE AIRSPEED (KNOTS)

FIGURE 8
LEVEL FLIGHT PERFORMANCE
EH-1X USA S/N 69-15920 T53-L-13B LE208258

AVG GROSS WEIGHT (LB)	AVG LONG. CG LOCATION (FS)	AVG DENSITY ALTITUDE (FT)	AVG OAT (° C)	AVG ROTOR SPEED (RPM)	AVG C_T $\times 10^4$	AIRCRAFT CONFIG.
8380	136.3	6130	17.5	326	34.86	EH-1X(2)

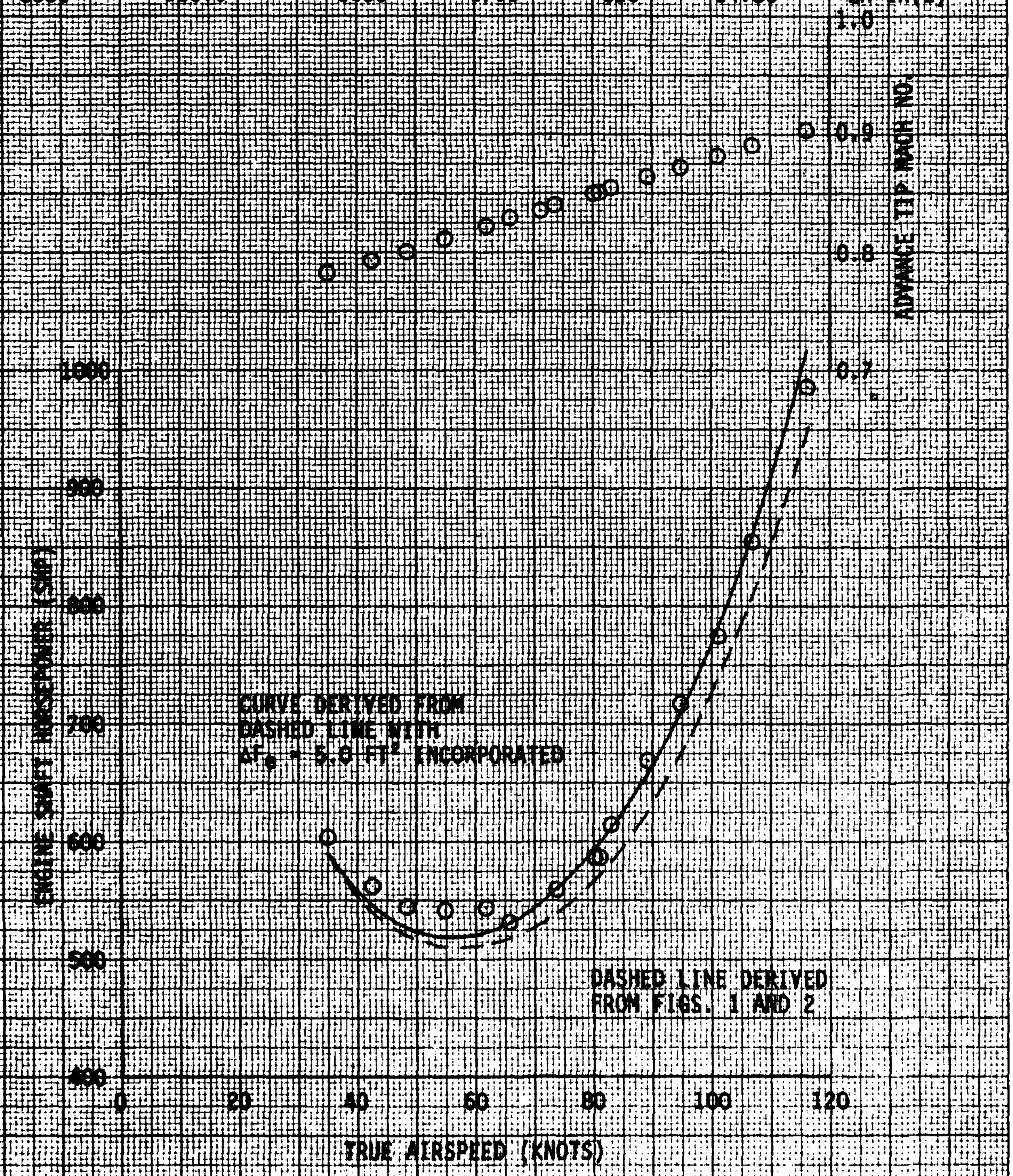
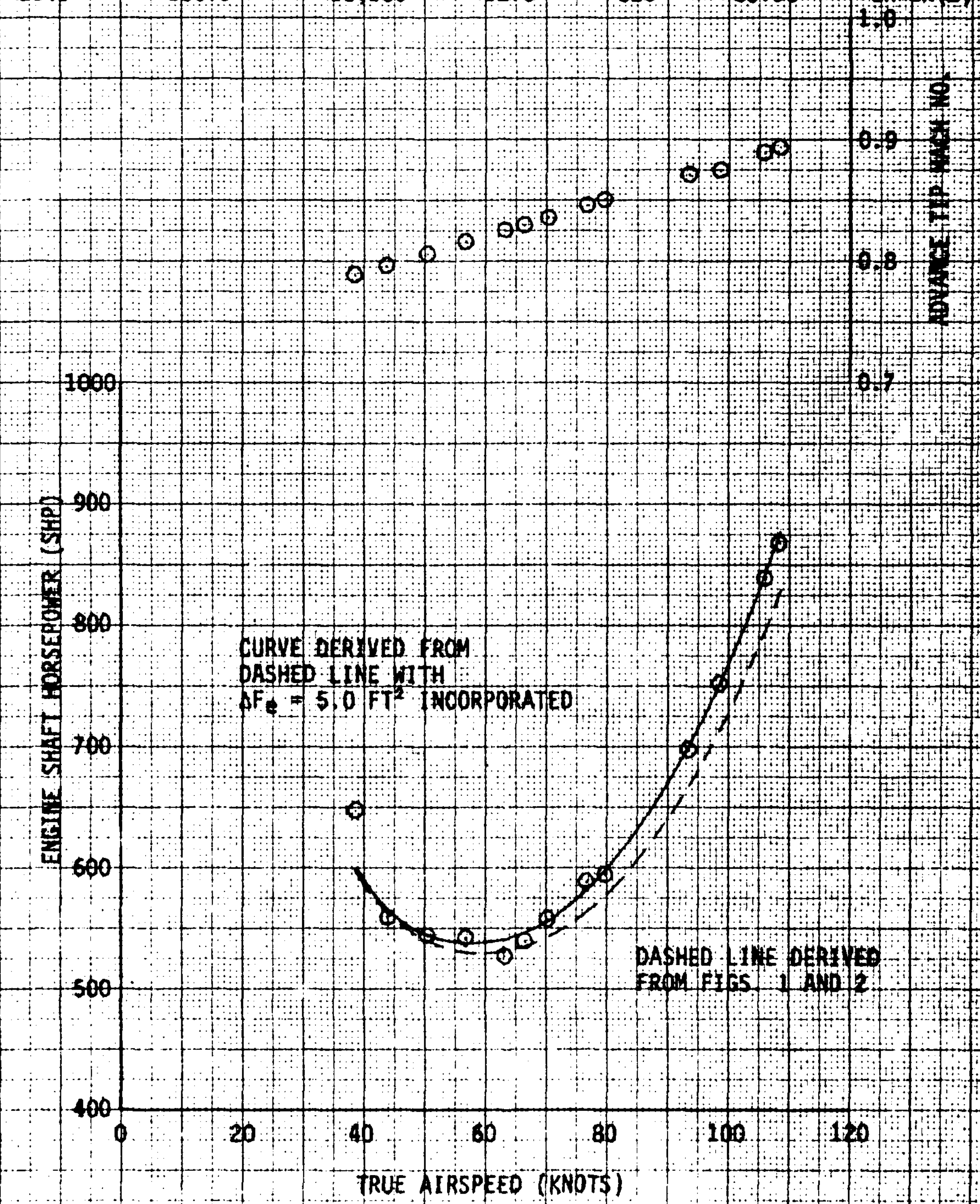
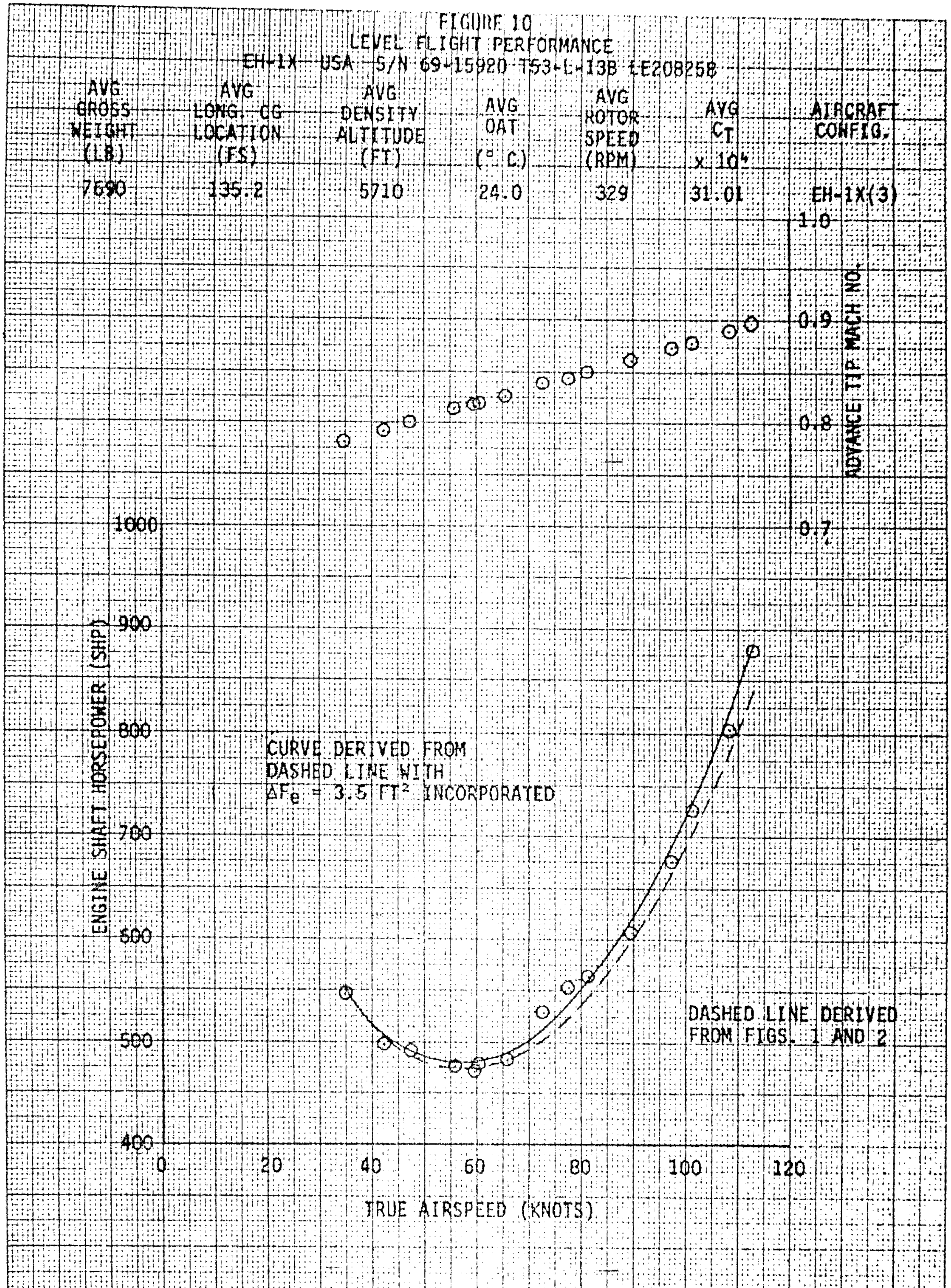


FIGURE 9
LEVEL FLIGHT PERFORMANCE
EH-1X USA S/N 69-15920 T53-L-13B LE208258

AVG GROSS WEIGHT (LB)	AVG LONG. CG LOCATION (FS)	AVG DENSITY ALTITUDE (FT)	AVG OAT (° C)	AVG ROTOR SPEED (RPM)	AVG C_T x 10^4	AIRCRAFT CONFIG.
8340	136.3	10,100	12.5	323	39.96	EH-1X(2)

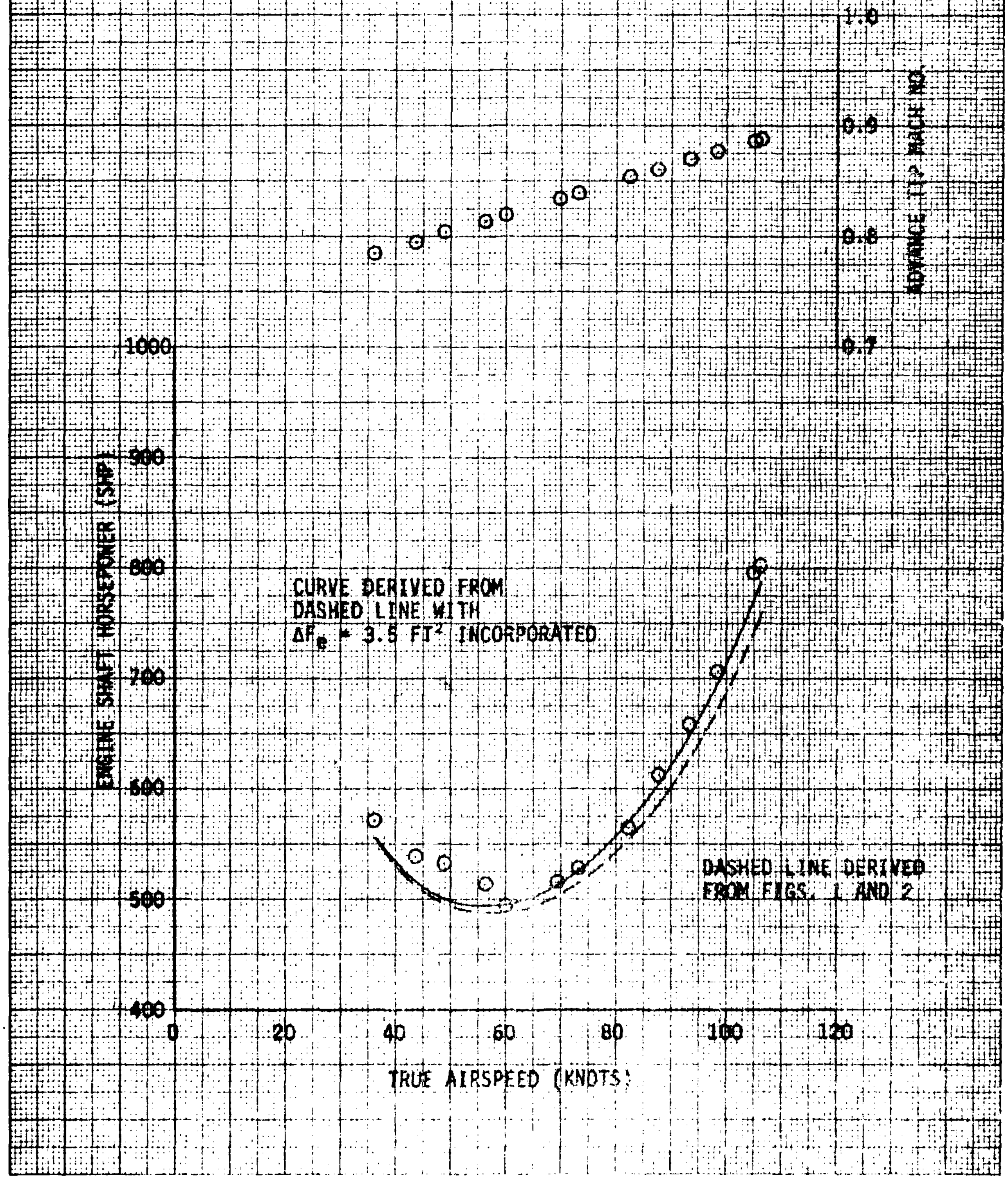




BEST AVAILABLE COPY

FIGURE 11
LEVEL FLIGHT PERFORMANCE
EH-1X USA S/N 69-15920 T53-L-13B LE208258

AVG GROSS WEIGHT (LB)	AVG LONG. CG LOCATION (FS)	AVG DENSITY ALTITUDE (FT)	AVG OAT (° C)	AVG ROTOR SPEED (RPM)	AVG C_T $\times 10^4$	AIRCRAFT CONFIG.
8040	135.3	8050	23.0	328	35.05	EH-1X(3)



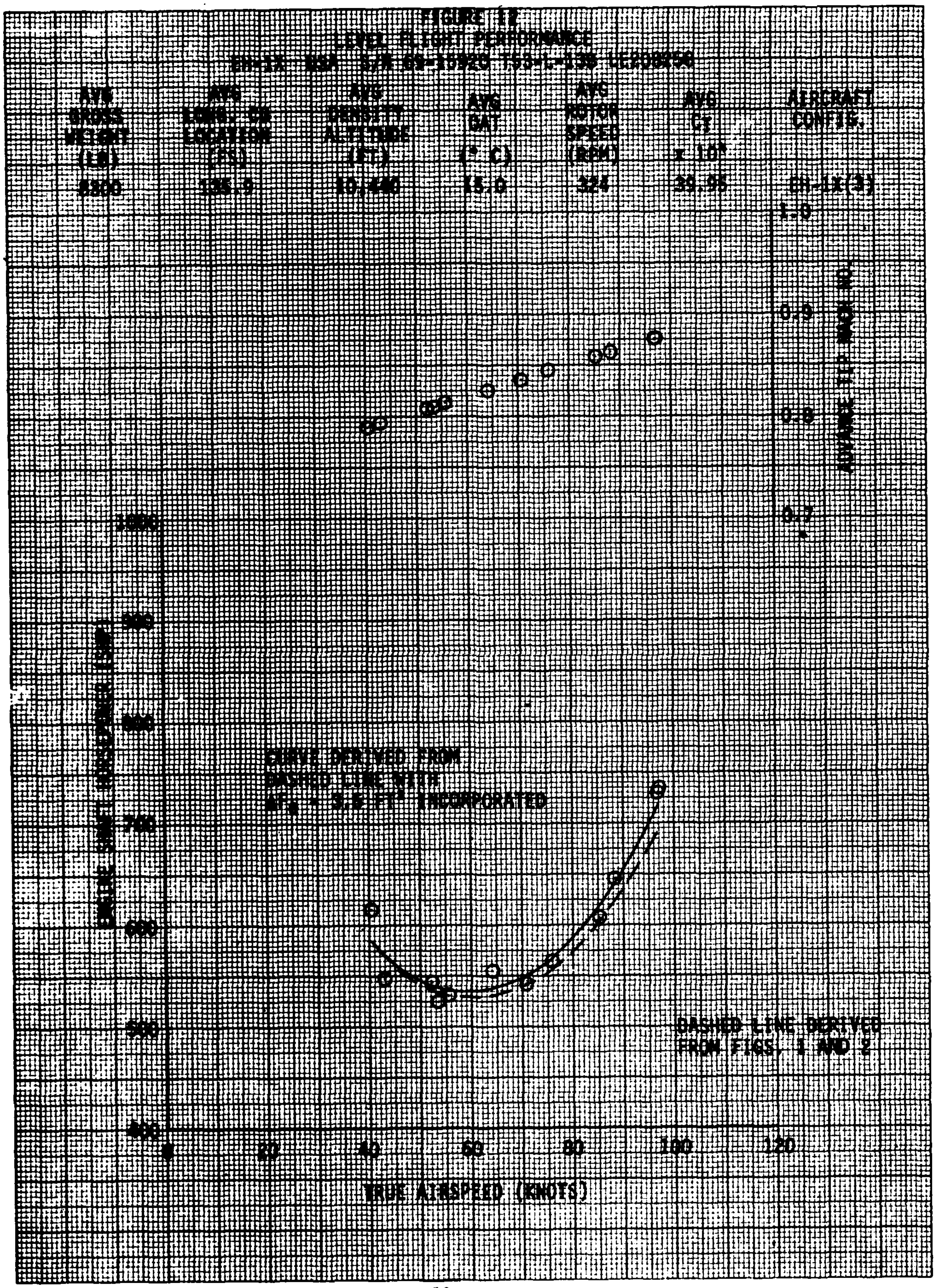


FIGURE 17
LEVEL FLIGHT PERFORMANCE
OH-1X USA S/N 69-15920 T53-L-13B
AVG GROSS WEIGHT (LB) 8300
AVG LONG. CG LOCATION (FS) 135.9
AVG DENSITY ALTITUDE (FT) 10,440
AVG OAT (°C) 15.0
AVG ROTOR SPEED (RPM) 324
AVG C_T x 10^4 39.95
AIRCRAFT CONFIG. OH-1X(3)
ADVANCE TIP MACH NO.
1.0
0.9
0.8
0.7
ENGINE SHAFT HORSEPOWER (SHP)
1000
900
800
700
600
500
400
CURVE DERIVED FROM DASHED LINE WITH ΔF_e = 3.5 FT^2 INCORPORATED
DASHED LINE DERIVED FROM FIGS. 1 AND 2
0
20
40
60
80
100
120
TRUE AIRSPEED (KNOTS)

FIGURE 13
LEVEL FLIGHT PERFORMANCE
EH-1X USA S/N 69-15920 T53-L-13B LE20825B

AVG GROSS WEIGHT (LB)	AVG LONG. CG LOCATION (FS)	AVG DENSITY ALTITUDE (FT)	AVG OAT (° C)	AVG ROTOR SPEED (RPM)	AVG CT $\times 10^4$	AIRCRAFT CONFIG.
7380	135.8	6980	23.0	329	30.89	EH-1H(4)

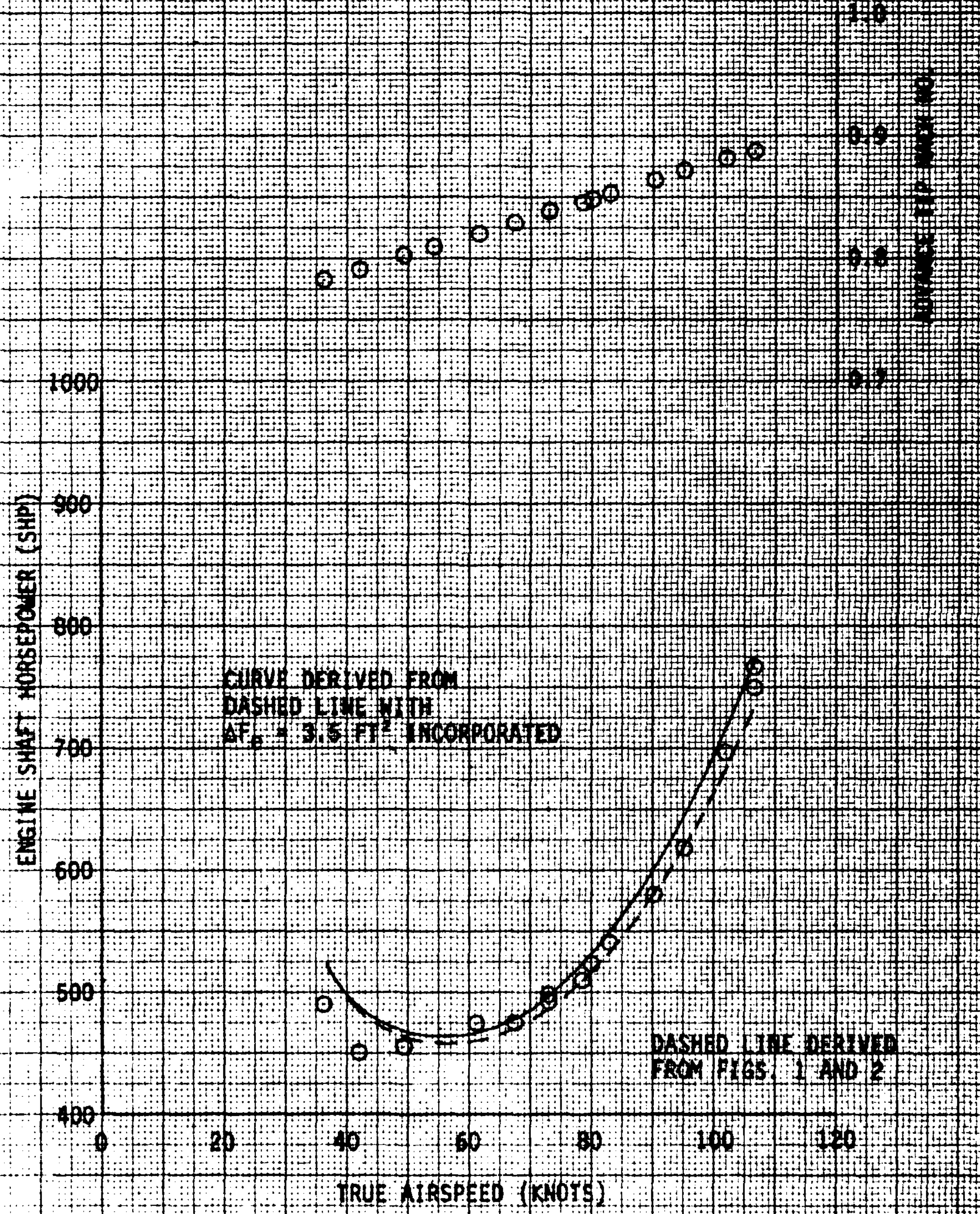


FIGURE 14
LEVEL FLIGHT PERFORMANCE
EH-1X USA S/N 69-15920 T53-L-13B LE20825B

AVG GROSS WEIGHT (LB)	AVG LONG. CG LOCATION (FS)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	AVG C_T $\times 10^4$	AIRCRAFT CONFIG.
7950	135.9	8520	23.5	329	34.95	EH-1H(4)

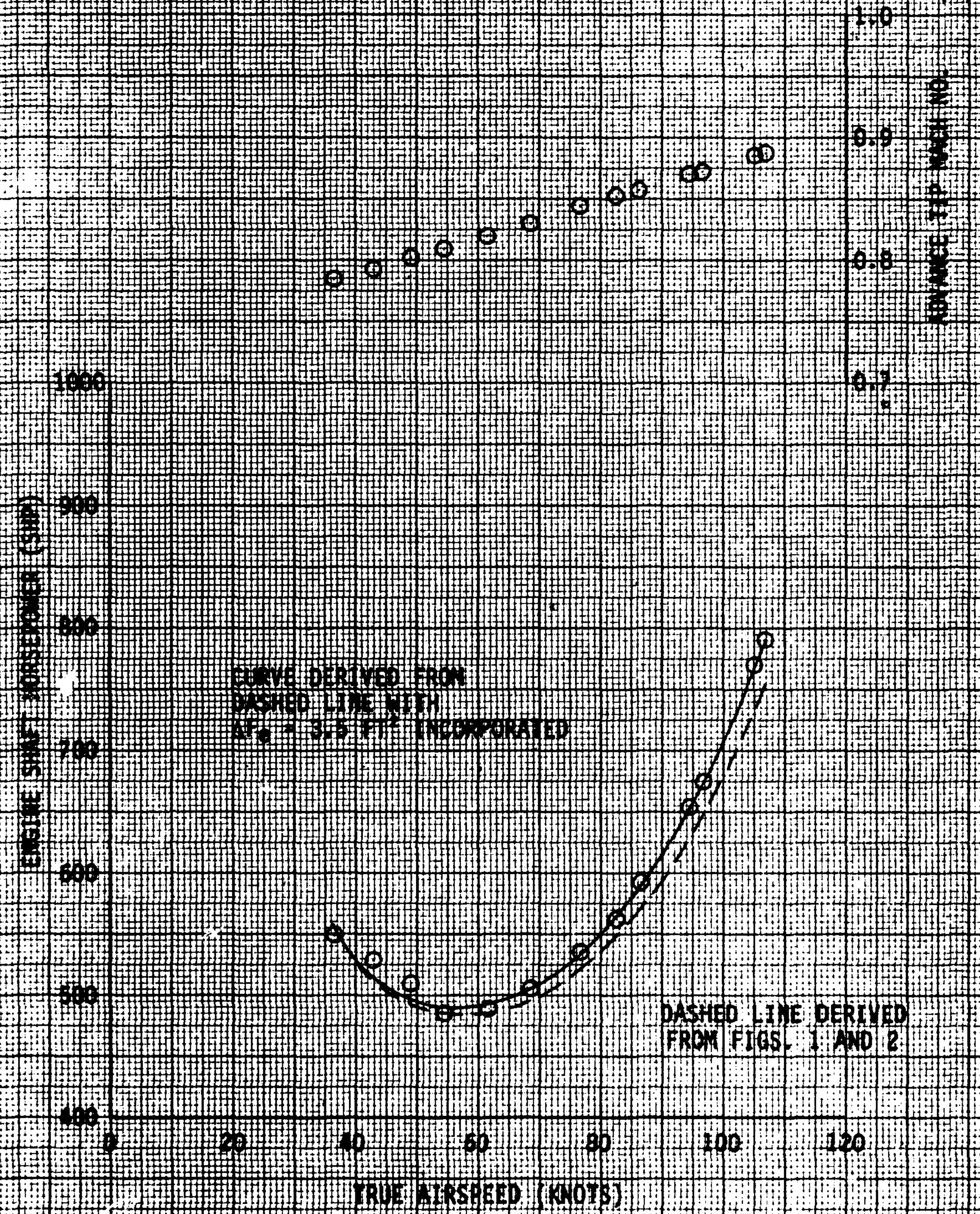
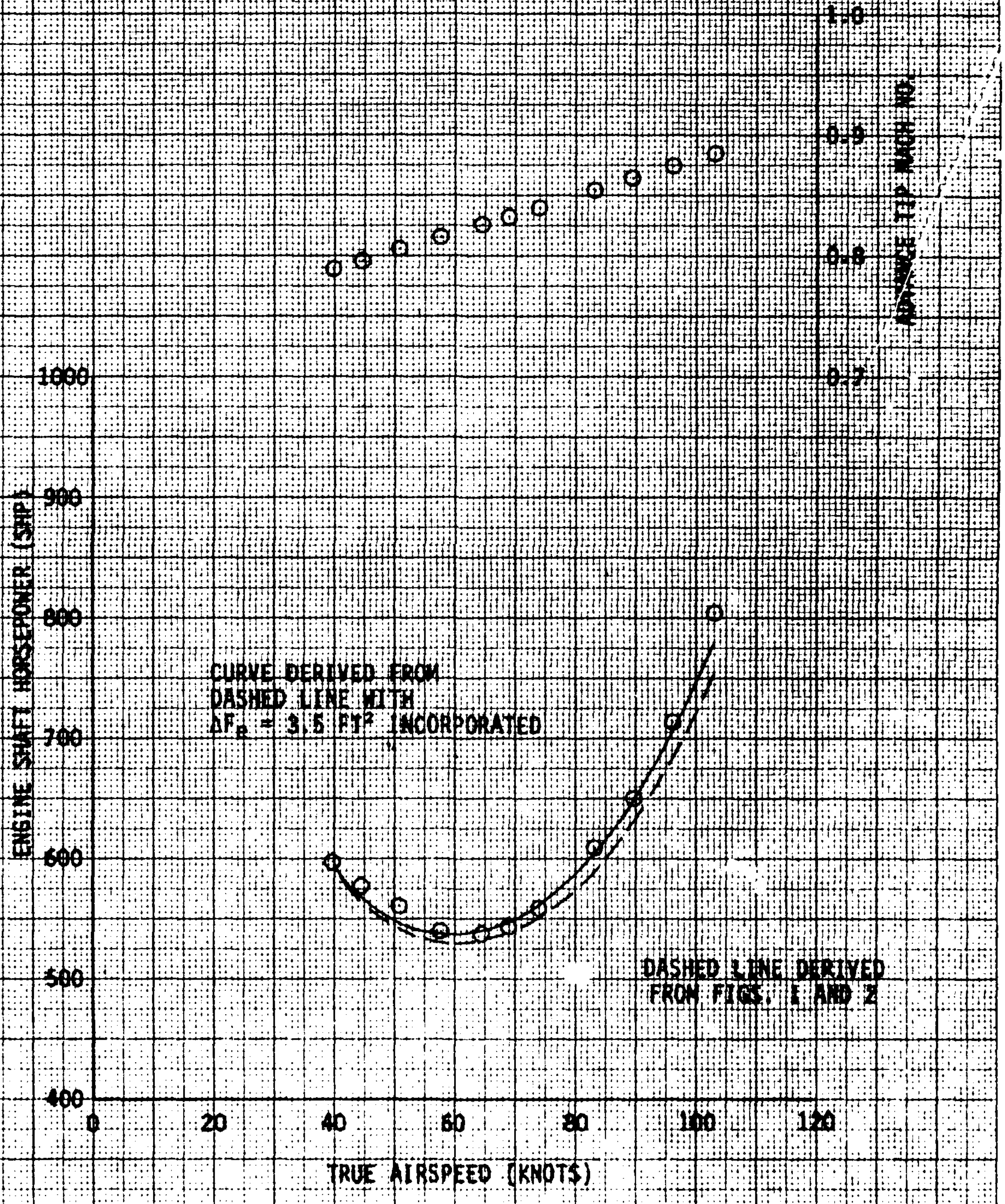


FIGURE 15
LEVEL FLIGHT PERFORMANCE
EH-1X USA S/N 69-15920 T53-L-13B LE208258

AVG GROSS WEIGHT (LB)	AVG LONG. CG LOCATION (FS)	AVG DENSITY ALTITUDE (FT)	AVG OAT (° C)	AVG ROTOR SPEED (RPM)	AVG C_T x 10^4	AIRCRAFT CONFIG.
8300	135.9	10,720	16.5	326	39.81	EH-1H(4)



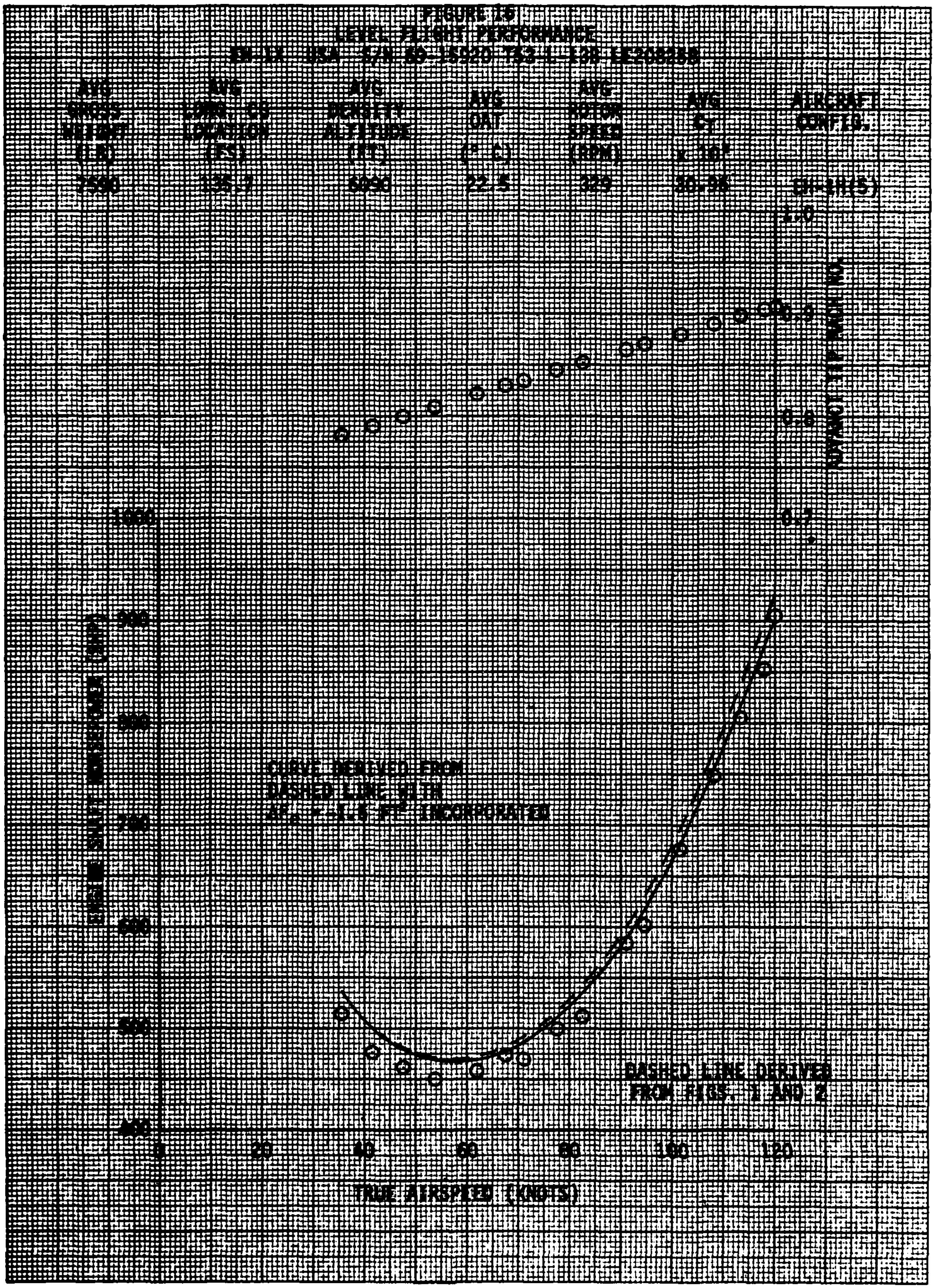


FIGURE 16
LEVEL FLIGHT PERFORMANCE
AVG GROSS WEIGHT (LB) 7590
AVG LONG. CG LOCATION (FS) 135.7
AVG DENSITY ALTITUDE (FT) 6090
AVG OAT (°C) 22.5
AVG ROTOR SPEED (RPM) 329
AVG CT
AIRCRAFT CONFIG.
ADVANCING TIP MACH NO.
ENGINE SHAFT HORSEPOWER (SHP)
CURVE DERIVED FROM DASHED LINE WITH
DASHED LINE DERIVED FROM FIGS. 1 AND 2
TRUE AIRSPEED (KNOTS)

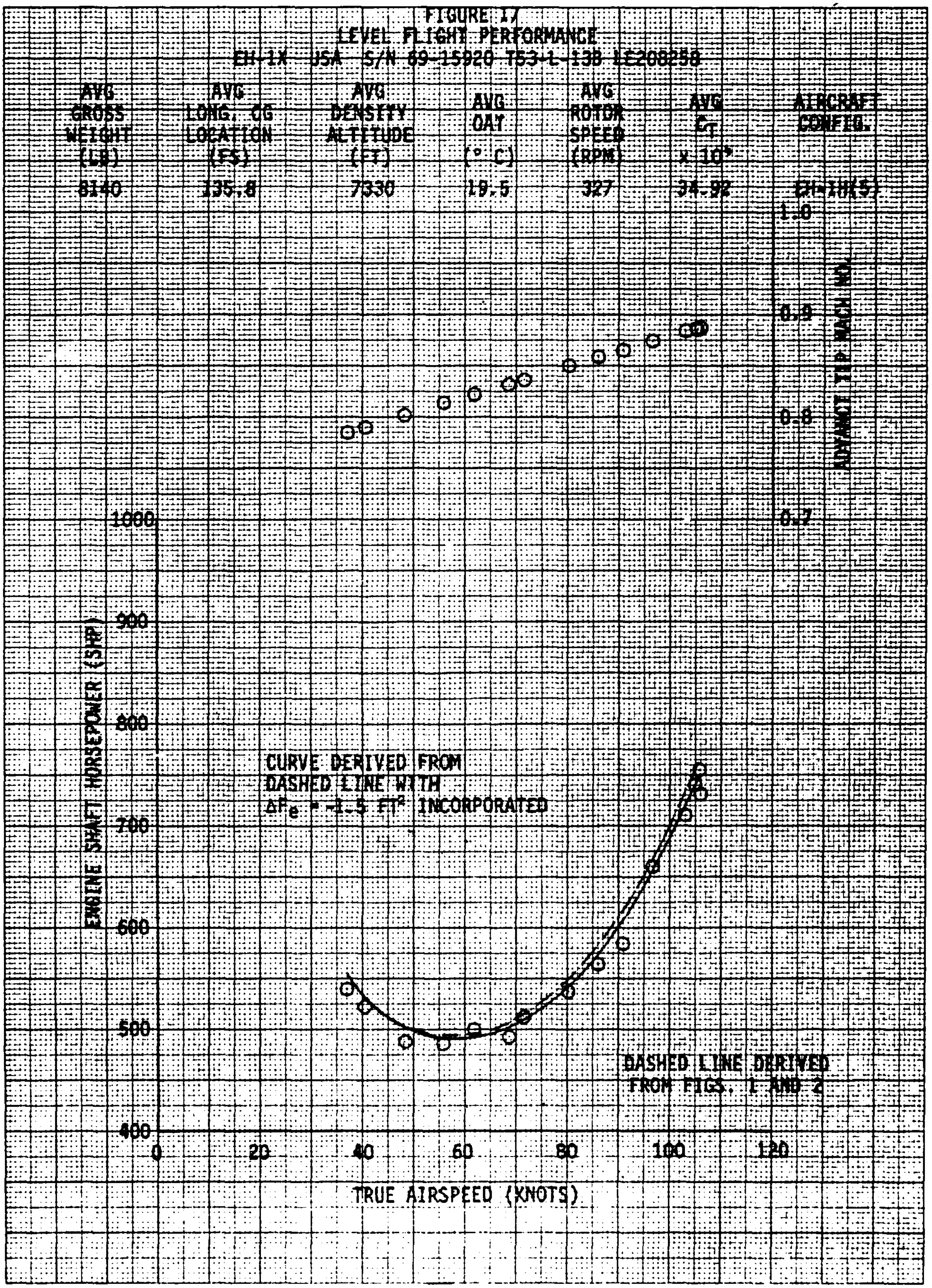
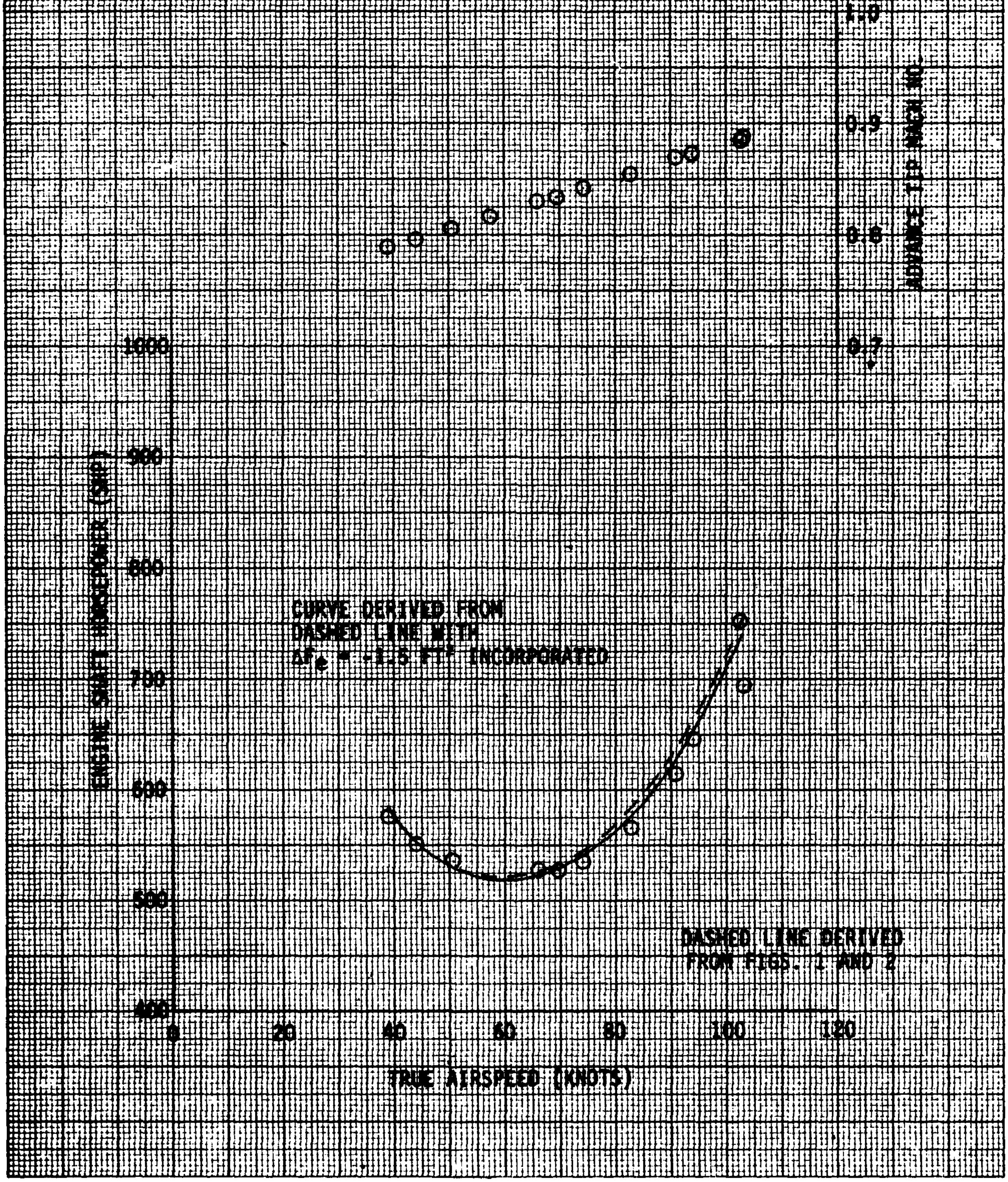


FIGURE 17
LEVEL FLIGHT PERFORMANCE
EH-1X USA S/N 69-15920 T53-L-13B LE208258
AVG GROSS WEIGHT (LB)
AVG LONG. CG LOCATION (FS)
AVG DENSITY ALTITUDE (FT)
AVG OAT (° C)
AVG ROTOR SPEED (RPM)
AVG C_T x 10^4
AIRCRAFT CONFIG.
8140
135.8
7330
19.5
327
34.92
EH-1H(5)
ADVANCE TIP MACH NO.
ENGINE SHAFT HORSEPOWER (SHP)
CURVE DERIVED FROM DASHED LINE WITH ΔF_e = -1.5 FT² INCORPORATED
DASHED LINE DERIVED FROM FIGS. 1 AND 2
TRUE AIRSPEED (KNOTS)

FIGURE 18
LEVEL FLIGHT PERFORMANCE
EH-1X USA S/N 69-15920 T53-L-13B LE208258

AVG GROSS WEIGHT (LB)	AVG LONG. CG LOCATION (FS)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	AVG C_T $\times 10^4$	AIRCRAFT CONFIG.
8230	136.4	10,250	11.0	322	39.67	EH-1H(5)



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